

How is COVID-19 reshaping activity-travel behavior? Evidence from a comprehensive survey in Chicago

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ABSTRACT

The novel COVID-19 pandemic has caused upheaval around the world and has led to drastic changes in our daily routines. Long-established routines such as commuting to workplace and in-store shopping are being replaced by telecommuting and online shopping. Many of these shifts were already underway for a long time, but the pandemic has accelerated them remarkably. This research is an effort to investigate how and to what extent people's mobility-styles and habitual travel behaviors have changed during the COVID-19 pandemic and to explore whether these changes will persist afterward or will bounce back to the pre-pandemic situation. To do so, a stated preference-revealed preference (SP-RP) survey is designed and implemented in the Chicago metropolitan area. The survey incorporates a comprehensive set of questions associated with individuals' travel behaviors, habits, and perceptions before and during the pandemic, as well as their expectations about the future. Analysis of the collected data reveals significant changes in various aspects of people's travel behavior. We also provide several insights for policymakers to be able to proactively plan for more equitable, sustainable, and resilient cities.

1. Introduction

The first reported case of the novel coronavirus (i.e. SARS-CoV-2) was confirmed in November 2019. Not far thereafter, the World Health Organization (WHO) recognized this viral outbreak as the COVID-19 pandemic, and has since recorded over 12.7 million cases world-wide, with total deaths surpassing 560,000 as of July 31, 2020 (WHO, 2020). Various national and international public health organizations, including the U.S. Centers for Diseases and Control and Prevention (CDC) and WHO have been closely monitoring this situation, and recommending preventative measures to limit or slow down the spread of the virus (CDC, 2020; WHO, 2020). In heeding with these guidelines, countries around the globe have enacted regulatory actions that vary from advisory recommendations to legal enforcements.

Consequently, rapid and drastic changes have become apparent in people's mobility-styles (i.e., lifestyles with respect to mobility, activity-travel habits, predispositions, and higher-level orientations) among other aspects of their activity-travel behavior. Mobility-styles are usually resistant to change in normal conditions (Berliner et al., 2015; Frei et al., 2015; Gärling and Axhausen, 2003; Götz et al., 1997; Schönfelder and Axhausen, 2010; Shamshiripour et al., 2020; Vij et al., 2013), but not necessarily during a prolonged, severe pandemic. The unique circumstances introduced by this novel pandemic have caused many to re-examine their habits and priorities, resulting in considerable changes in the way people

perform their everyday tasks. The preventive measures issued by advisory and regulatory agencies such as social distancing, coupled with public fear of contagion, have caused a significant fraction of people to change their daily routines for the past few months. Notably, major transitions have been made from in-store shopping, business meetings, and long-distance commutes to online shopping, telecommuting, and road trips to avoid crowds and physical interactions.

While such significant transitions have been reported in many metropolitan areas, it remains unclear as to how and what extent various socio-economic segments of the population have adjusted to the situations surrounding the pandemic. Furthermore, the distinction between the types of adjustments that will persist post-pandemic and the adjustments that will bounce back to their pre-pandemic situation remains an understudied area. Also, very little is known about the individual-level variations in the levels of risk-aversion, the levels of satisfaction with the 'new normal' during the pandemic or plans for a post-pandemic future. Such information is critical for updating our transportation demand models so that they can be used as reliable and useful planning tools towards sustainable and resilient cities.

The present research focuses on bridging these gaps by shedding light on the dynamics of people's activity-travel behavior during and after the Covid-19 pandemic. We pay special attention to potential changes in preferences and behaviors around daily activities—including shopping, working, and other outdoor activities—as well as multiple travel-oriented decisions, such as mode choice and long-distance travel behavior. The

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research framework is designed as a longitudinal analysis encompassing multiple survey waves to continually monitor how individuals' travel attitudes, habits, and behaviors evolve over the course of the COVID-19 pandemic. Finally, this study presents the preliminary results of the first wave of the survey, which is designed as a stated preference-revealed preference (SP-RP) survey using an online platform.

The RP portion of the survey mostly collects retrospective information from the respondents about their travel attitudes, habits, and behaviors prior to and during the COVID-19 pandemic. The SP portion further asks the respondents about how they perceive the future. The survey puts this information together with socio-demographic details and health-related indicators such as indicators of whether the respondents have been tested positive for COVID-19 or they have pre-existing medical conditions.

The remainder of this article is structured as follows: In [Section 2](#) we review the underlying literature on people's activity-travel behavior during the pandemic situations. Afterwards in [Section 3](#), we present comprehensive information about the survey design and implementation, as well as general descriptions on the collected data. Expanding the discussions, then, the study findings will be discussed in [Sections 4 and 5](#). After that in [Section 6](#), we put the results into perspective for planning towards a more sustainable, resilient, and equitable future. In the end, the article concludes with a summary of the findings and potential avenues for future research.

2. Background

Reviewing the underlying literature, a limited number of studies can be found on the impacts of outbreaks on the transportation sector.

Focusing on leisure travels, [Wen et al. \(2005\)](#) analyzed the impacts of the SARS outbreak on the travel behavior of Chinese domestic tourists. The authors observed that the outbreak had greatly affected people's life, work, and travel behavior. Besides, the decrease in travel was found to be associated with a combination of internal motivations (e.g., perceived risks) and external enforced measures (e.g., travel bans, stay-at-home orders). This research, however, did not explicitly explore the effects of the outbreak on the post-outbreak world. Focusing on the international air travel, [Liu et al. \(2010\)](#) studied the effects of the same outbreak on air travel between the U.S. and three destinations: China, Hong Kong, and Taiwan. Highlighting the influence of lifestyles on travel behavior during an outbreak, the authors found that although the frequency of these international trips reduced for all countries, the level of risk was perceived differently among those countries.

In another study, [Fenichel et al. \(2013\)](#) examined more than 1.7 million detailed flight records to analyze air travelers' behavioral responses to the H1N1 pandemic that occurred in 2009. The authors estimated that the overall concerns over the H1N1 influenza (as measured by Google Trends) accounted for 0.34% of missed flights during the pandemic. According to this study, people respond to epidemiological risks with behavioral changes.

Focusing on public transit trips, [Kim et al. \(2017\)](#) analyzed the smart card data in Seoul before and after the MERS outbreak in South Korea. The authors observed that individuals living in neighborhoods with higher land prices decreased their transit trips more than others. Besides, the fear of exposure was significantly associated with changes in travel behavior. Focusing on the relationship between the changes in travel behavior and built environment settings, they found that land price, location of MERS hotspots, number of businesses, seniors population, and number of restaurants might significantly influence transit ridership during the outbreak.

More recently, [Hotle et al. \(2020\)](#) investigated risk perception and risk mitigation of travel-related decisions concerning influenza to characterize: 1) the risk perceptions, 2) the risk mitigation decisions when one is infected and wants to prevent spreading it, and 3) risk mitigation decisions when one is not infected and wants to minimize the exposure. The risk perception analyses showed that personal experience of having influenza-like symptoms as well as being female significantly increased risk perception at the places that one performs mandatory and medical-related activities.

Moreover, the risk mitigation analyses highlighted that individuals are less likely to travel to places where they perceive a medium or high risk of exposure to the Influenza virus. The authors also found that high perceived risks do not lead people to travel to their workplaces less frequently.

There are also a limited, but growing, number of studies focusing on the impact of recent COVID-19 pandemic on the transportation sector (e.g., [De Vos, 2020](#); [Ito et al., 2020](#); [Lee and Lee, 2020](#); [Molloy et al., 2020](#); [Sobieralski, 2020](#)). In particular, there exists a dearth of research on the changes in travel patterns caused by the current COVID-19 pandemic. In a short but informative study, [De Vos \(2020\)](#) discussed the potential implications of social distancing on daily travel patterns and, accordingly, provided some suggestions for policymakers. The authors highlighted that stay-at-home might be a threat to individuals' subjective well-being, causing limited physical activities and social isolation. According to this study, promoting active travel behavior is a potential solution for policymakers to encourage individuals to maintain a satisfactory level of well-being.

Focusing on the airline industry in the U.S., [Sobieralski \(2020\)](#) studied the interactions among economic and industry variables in the COVID-19 pandemic in which reductions in capacity of airlines are growing, and the post-stimulus employment requirements expire. The author found that the estimated job loss in the airline industry is around 7% of the airline workforce, with an upper bound of over 13%. Moreover, the author highlighted the high vulnerability of the airline industry during such uncertain periods as the current pandemic and showed that the adverse effects of the current uncertainty shocks might last for more than four years. In another study, [Molloy et al. \(2020\)](#) investigated the changes in travel behavior due to the spread of the COVID-19 pandemic in Switzerland. Focusing on different income groups as well as various accessibility states, they suggested a few first insights into how the spread of the disease can be limited in the study context.

3. Data collection and description

3.1. Survey design and general demographics

We designed a travel behavior survey focusing on the dynamics of daily travel behavior, as well as multiple aspects of people's long-term travel habits, attitudes, and preferences. The survey is implemented in the Chicago metropolitan area (including the counties of Cook, DuPage, Kane, Kendall, Lake, McHenry, and Will), Illinois, the U.S. The spatial distribution of the survey respondents and details of the information collected in the survey are elaborated in [Section 3.2](#), as well as [Sections 4 and 5](#). The focus of the present subsection is on higher-level discussions around the survey, including its structure and temporal coverage.

Combining stated preference (SP) and revealed preference (RP) methods, the survey was structured to collect information in three major categories: 1) socio-demographic details such as residential location, age, gender, race, as well as the economic factors including individual job categories and annual household income; 2) health-related factors such as weight and height, and physical exercise habits, as well as COVID-19 exposure risk factors such as having pre-existing medical conditions and being in close contact with a confirmed case; and 3) an extensive set of questions about people's attitudes and perceptions, habits, and daily activity-travel behavior. In terms of the various aspects of activity-travel behavior, the survey covered online and in-store shopping, teleworking, physical exercise, mode choice, and air travel.

The survey questionnaire was distributed from April 25, 2020, to June 2, 2020, through the online platform of Qualtrics (UIC IRB protocol number: #2020-0395). We also implemented Google Map API to collect respondents' approximate residential locations in the online questionnaire ([Fig. 1](#)). As shown in [Fig. 2](#), our collected sample is decently distributed all over the study area and covers neighborhoods with different levels of COVID-19 positive cases.

The survey was distributed among 1200 individuals older than 18. To ensure the quality of the collected data, we included multiple screening questions throughout the survey. For instance, in order to be able to flag

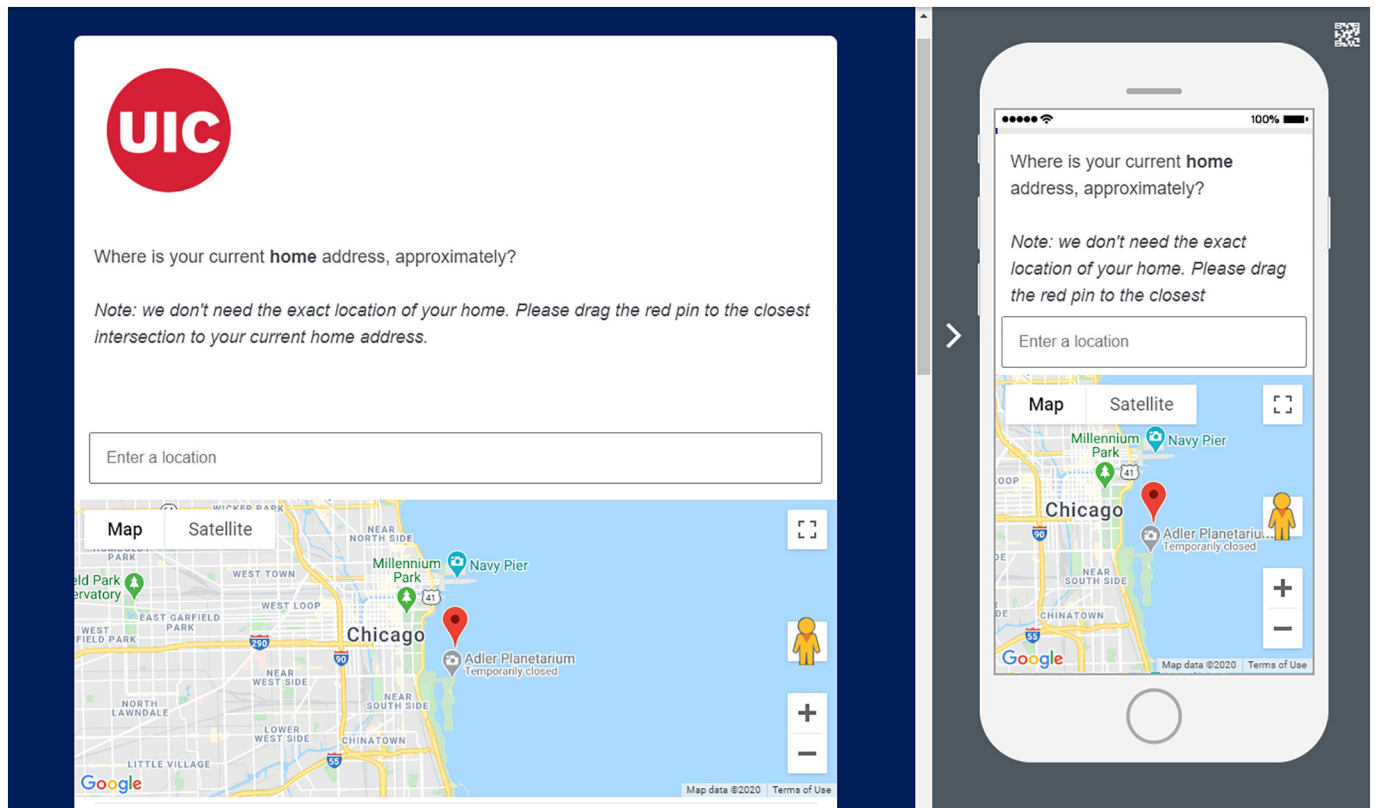


Fig. 1. A sample screenshot from the questionnaire.

those who responded to the questions without paying enough attention, we embedded a few questions and asked the respondents to choose a specific option. Also, we monitored the response time for each section to ensure that the respondents spent enough time on answering the questions. As another quality control measure, we also monitored the duration of the time that each respondent spent on the entire survey to exclude overly fast responses (with a 10-min cut off point). Furthermore, the critical socio-demographic questions were designed in a similar way to the National Household Travel Survey 2017 to facilitate validation and weighting. Besides, we asked Qualtrics to control for the distribution of respondents concerning the age, gender, and education to be aligned with the U.S. Census data for the region. After excluding those respondents who failed to meet the screening criteria mentioned above, 915 valid responses remained for the analysis.

Fig. 3 and Fig. 4 summarize frequency distributions of our collected data in terms of basic socio-demographics, including gender, age, education, individual job categories, and household income.

3.2. Distribution of factors related to health and exposure risk

First and foremost, we asked the respondents if they were confirmed to be infected by the novel coronavirus. According to the results, around 1% of the respondents reported to be a confirmed case, an additional 1% refused to answer this question, and the rest (i.e., 98%) responded “No” to this question. The results are quite similar to statistics reported by the Illinois Department of Public Health (IDPH) as of June 6, 2020 (IDPH, 2020). In another question, we also asked people if they felt they had symptoms of the COVID-19 disease in the past 14 days (see Fig. 5 (a)). Around 5% of the respondents (i.e., five times as high as the proportion of the confirmed cases) reported having the symptoms, indicating the high importance of providing enough testing instruments and facilities to the responsible organizations to facilitate the screening process.

Also, we asked the respondents to indicate if they had close contact with a person who was confirmed to have the virus (see Fig. 5 (b)). The

designated question had three choice alternatives to distinguish between those who had the contact within the past 14 days (~3%) and before the past 14 days (also ~3%). Furthermore, we asked the respondents if they had pre-existing conditions that can elevate the severity of the disease in case of infection. Fig. 6 is set out to summarize the responses while breaking down by two primary age groups: the seniors older than 65 and the younger individuals. As can be seen, around 52% of seniors and 27% of younger individuals believed that they had a pre-existing condition.

4. Economically vulnerable groups

This section is devoted to uncovering the most economically vulnerable groups of society. Towards this, we focused on two main areas: 1) the burden imposed on people due to losing their jobs either temporarily or permanently, and 2) the changes that people made in their expenditures on shopping for errands. Identifying the most economically vulnerable groups of the society provides essential insights into the priorities while planning for a more equitable future. Moreover, it also provides essential insights to enrich our understanding of the dynamics of activity-travel behavior in the future. A prerequisite to an unbiased analysis of who will change his/her travel behavior and how is an accurate recognition of how much the expenditure power of each person has been affected.

Looking into the changes of unemployment status, our results show a considerably concerning gap between the unemployment rates among the former full-time and part-time workers. Fig. 7 (a) shows how the COVID-19 pandemic has affected full-time workers. Around 14% of such workers indicated that they were temporarily laid off. It is worthy to note that, although the unemployment of such individuals is temporary, the side effects of losing their source of income for months might easily expand to the future for them even after starting to get paid. The economic complexities would be even harsher for around 5% of the full-time workers who lost their jobs permanently. Fig. 7. (b) shows similar information for the formerly part-time workers. As can be seen, 17% of part-time workers lost their jobs permanently (around 3.4 times as high as the full-time workers),

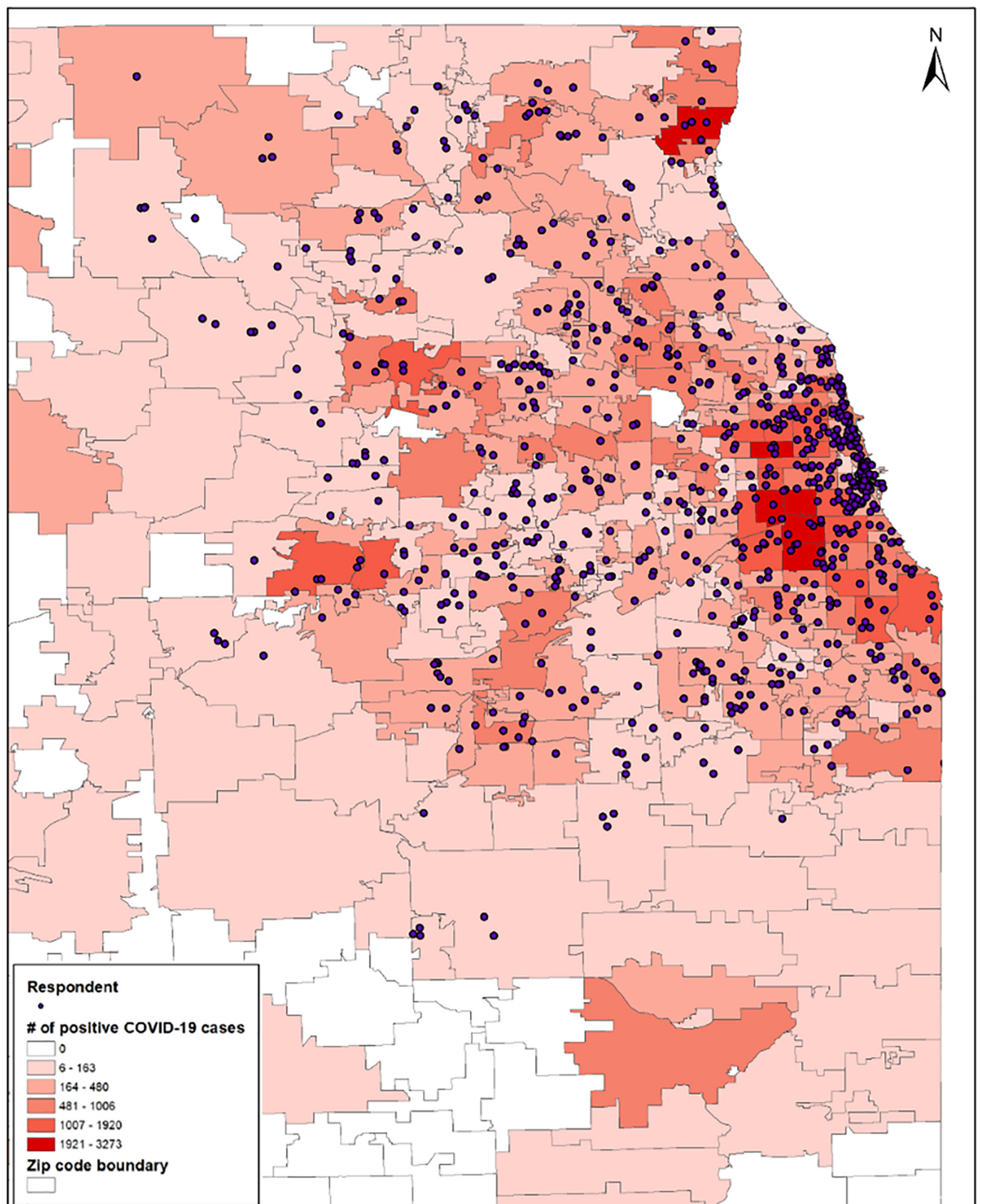


Fig. 2. Respondents' residential locations mapped on the number of COVID-19 positive cases (as of June 6, 2020) in each zip code within the Chicago metropolitan area.

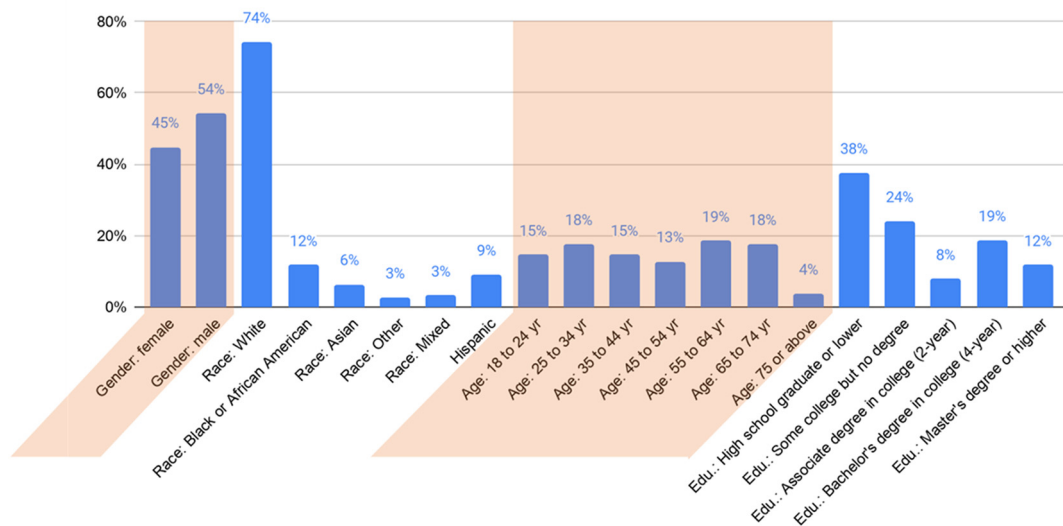


Fig. 3. Distribution of gender, race, age, and education level in the sample.

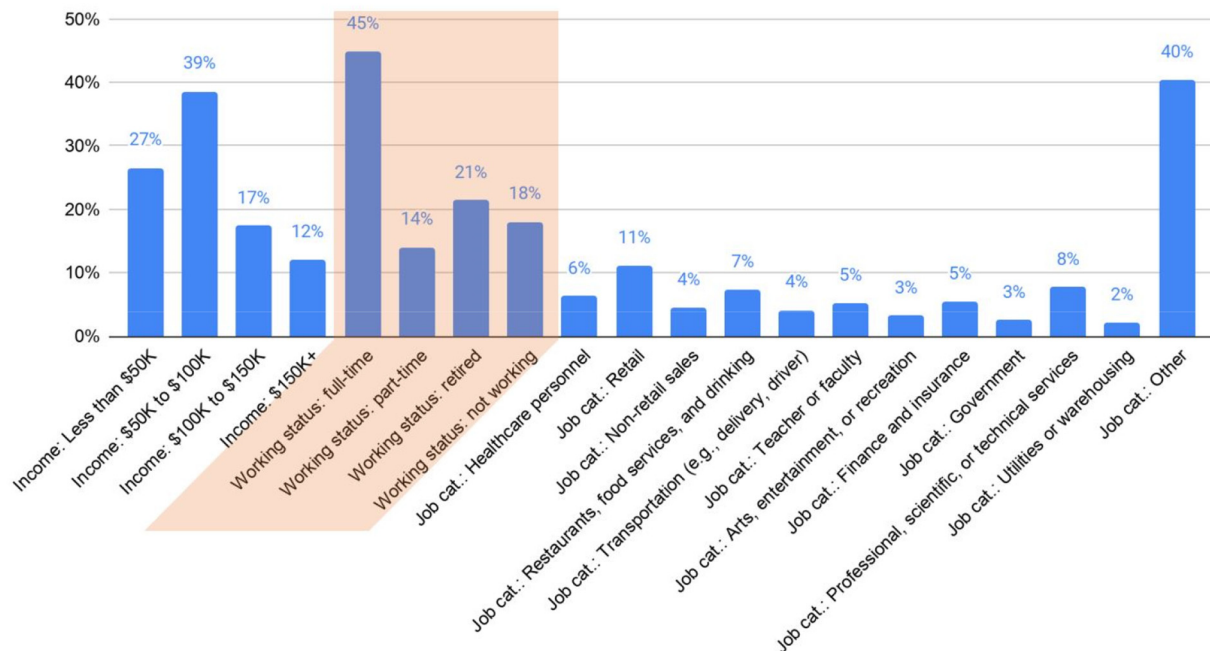


Fig. 4. Distribution of household annual income level, working status, and job categories in the sample.

and an additional 35% were temporarily laid off (around 2.5 times as high as the full-time workers). Put differently, more than half of part-time workers and 19% of full-time workers have lived the past few months without having been paid, which shows a 63% gap between the two groups.

Moving forward to the job categories, Fig. 8 depicts the unemployment-status changes observed for the various job categories discussed in Section 3.1. As can be seen in Fig. 8, the situation with workers in restaurants, food services, and bars as well as workers in the arts, entertainment, or recreation industries is considerably more alarming as compared to the rest of the workers. According to the results, more than 60% of such workers have been living without being paid during the COVID-19 pandemic. The highest rate of permanent loss of jobs also belongs to the same groups – more than 20% for both groups.

Fig. 9 depicts the unemployment-status changes for different household-income groups. As an alarming first insight, the results reveal that around 44% (i.e., 31% plus 13%) of those who live in very low-income households (i.e., an annual income of less than \$30 K) have been dealing with at least¹ one discontinued source of income. This number, according to Fig. 9 is four times as high as the corresponding number for those households who earn \$150 K or higher (i.e., 11%, which is the sum of 7% and 4%). This shows how severely the economic impacts hit the low-income groups of the society. Fig. 10 adds more details on the economic

¹ The income information is collected on the household-level while the unemployment status is collected on the individual-level. Therefore, what happened to the other members of the household remains unobserved.

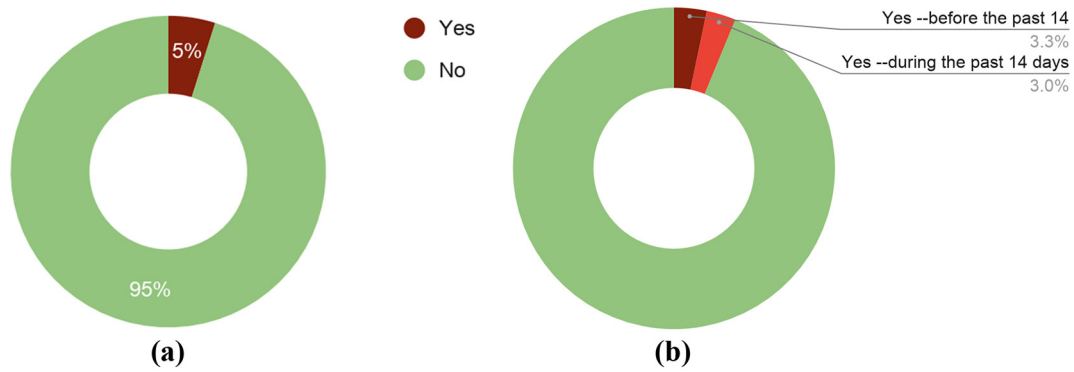


Fig. 5. Sample distribution of: (a) reported close contacts with confirmed cases of COVID-19, and (b) having COVID-19 symptoms in the past 14 days.

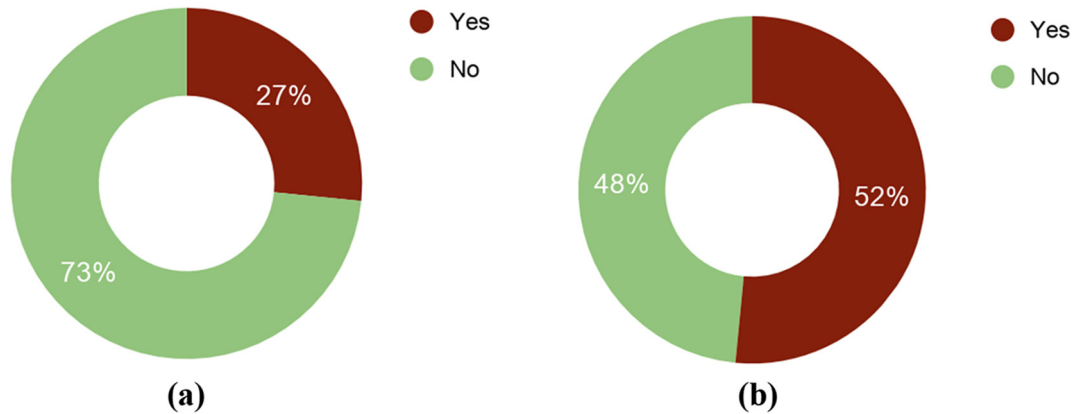


Fig. 6. Sample distribution of having pre-existing conditions, by age group: (a) younger than 65 (b), and older than 65.

effects of COVID-19 on low-income families. The following elaborates on this Figure.

As part of the survey, we also collected the individual expenditures on three errand-shopping categories: groceries, prepared meals, and other errands. Fig. 10 shows the average expenditures on each category for different income groups. As can be seen, all income groups have been expending more on groceries and meals, and less on other errands. This is understandable given that, these days, people have been less sensitive about how expensive an option is and more concerned about how safe and accessible it is. Focusing on low-income households, an average member of such families has been spending 37% more on their groceries. This makes sense, given that the more expensive stores have been adopting more safety measures to ensure the safety of their customers. Therefore, a low-income person who wants to minimize the risk of catching the virus may have to switch to more expensive alternatives. Similarly, grocery

online shopping alternatives (which are safer in terms of exposure to COVID-19) are also usually more expensive than their in-store shopping counterparts. Putting this observation on the low-income households (less than \$30 K) together with the last observation that such people have also been more prone to losing their job, brings us to the conclusion that they have been probably experiencing notably tough situations.

5. Attitudinal and behavioral changes caused by the COVID-19 pandemic

5.1. Working from home

In Section 4, we focused on identifying the economically vulnerable groups of the society and discussed the economic impacts in terms of average expenditures and losing jobs. In this section, we focus on the dynamics

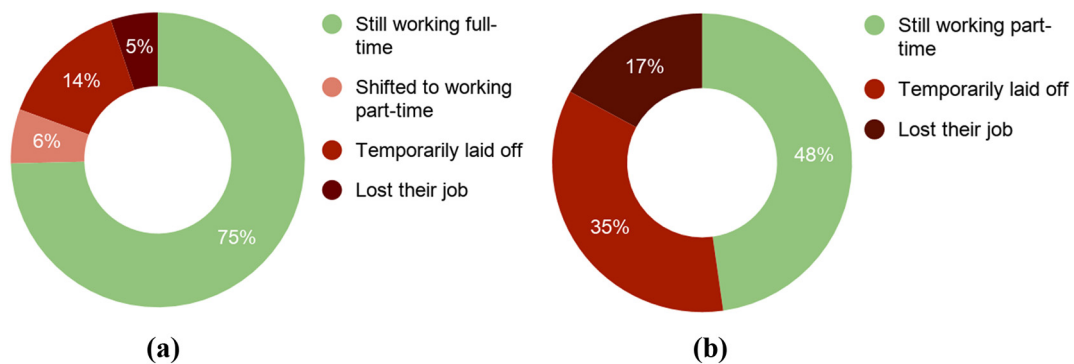


Fig. 7. Change in employment status during the pandemic for (a) full-time workers, (b) part-time workers.

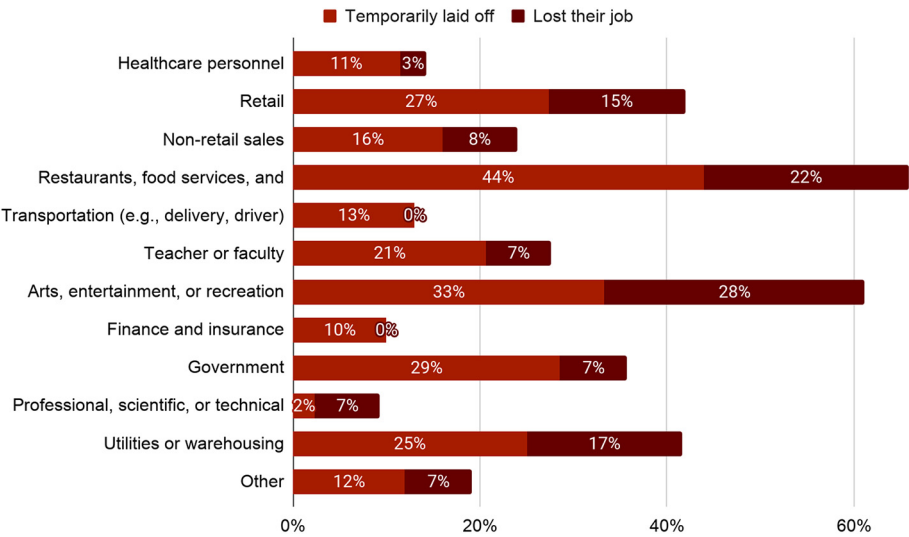


Fig. 8. The proportion of workers in each industry who were temporarily laid off *during* the pandemic, or lost their job.

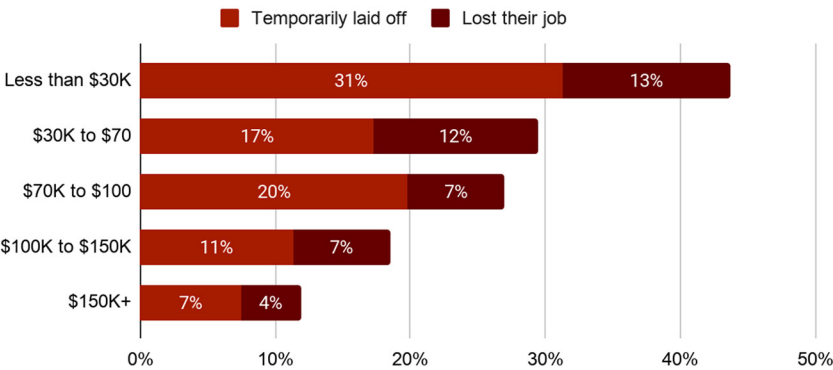


Fig. 9. The proportion of members of each household-income group who were temporarily laid off *during* the pandemic, or lost their job.

of working from home. The various aspects discussed in this section include: 1) the dynamics of working from home before and during the pandemic, and 2) the dynamics of work productivity before and during the pandemic.

Fig. 11 shows the frequency of working from home before and during the pandemic in our sample. As can be seen, around 71% of our respondents had not experienced working from home before the COVID-19 pandemic, while 15% were already working from home for at least 5 days a week.

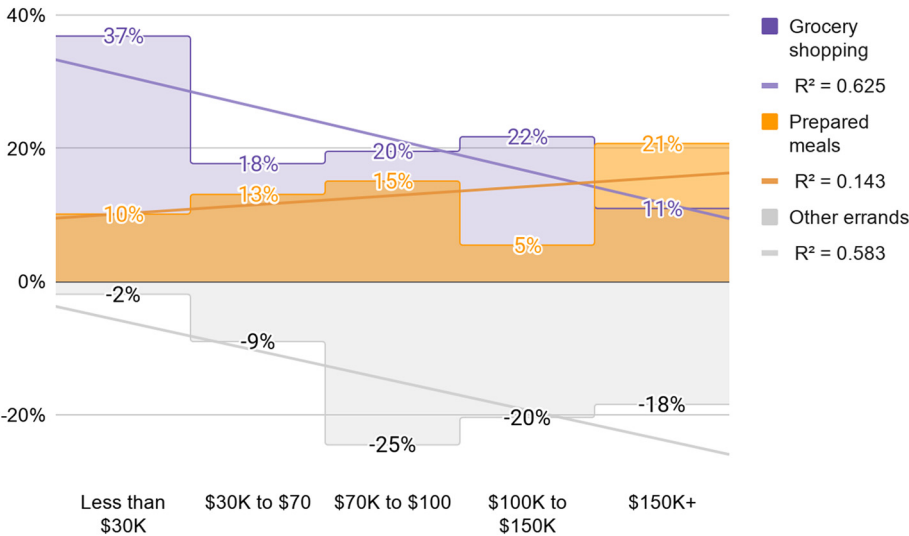


Fig. 10. Change in shopping expenditure *during* the pandemic: shopping for groceries, prepared meals, and errands.

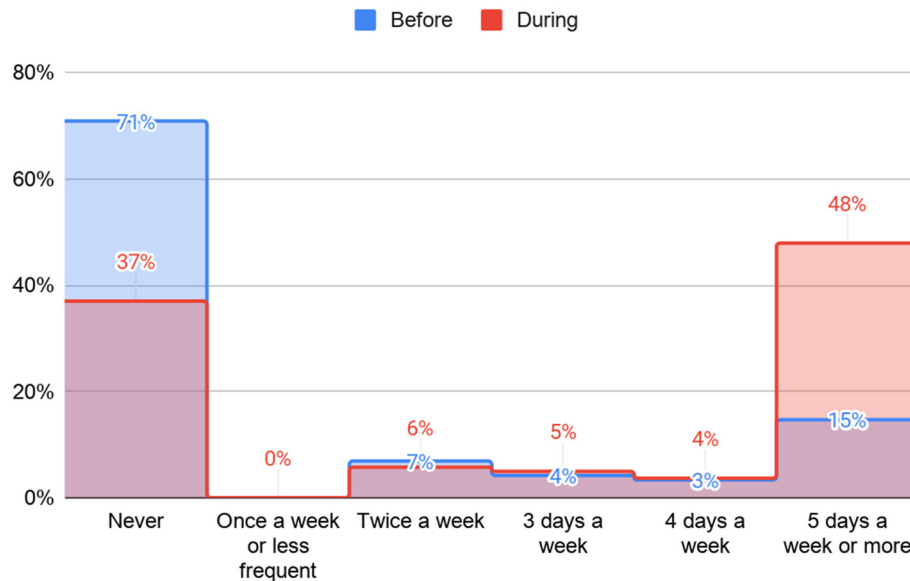


Fig. 11. Frequency of working from home, *before* and *during* the COVID-19 pandemic.

With the pandemic wave hitting the state of Illinois and the corresponding stay-at-home order, however, this pattern changed drastically, as shown by the red bars in this Fig. As can be seen, 37% of the respondents reported that they had not worked from home –even for a single day– during the endemic. Scrutinizing this category, we realized that around 9% out of the 34% are healthcare personnel, and the rest are those who work in retail stores, in the transportation industry, or have other service jobs. These are essential jobs that cannot be forced to stay home, and this fact highlights that there is a limit to how effective policies such as the stay-at-home order and the closure of non-essential businesses could enforce social distancing. The discussions in Section 6 will expand on this subject.

As part of the survey, we also asked those workers who have been working from home about how they evaluate their productivity as compared to the before COVID-19 situations. Fig. 12 summarizes the answers provided to us while distinguishing between two major groups of: 1) those who had not experienced working from home before the stay-at-home order but were doing so 5 days a week during it (named as “new telecommuters”), and 2) those who were working from home 5 days a week before and continued doing so during the stay-at-home order (named as “continuing telecommuters”). As can be seen, 59% (i.e., 41% + 16% + 2%) of new telecommuters believe that their productivity has been the same or higher. Notably, however, the rest 41% of the new telecommuters did not have a productive experience. The fact that both of these two groups constitute significant portions of the society sheds light on the importance of taking a closer look at the underlying heterogeneities. This importance becomes more evident given the concrete evidence from the literature suggesting that working from home can significantly alleviate traffic congestion and air pollution if adopted by a large portion of workers (Shabanpour et al., 2018).

To better understand the subject, we also asked the respondents about the factors that have been negatively and positively affecting

their productivity at home. They could choose multiple items. Fig. 13 (a) and Fig. 13 (b) summarize the frequency of the factors that have been negatively and positively affecting the productivity of working from home, respectively. The more frequent distractions at home (i.e., 61%) and lack of comfortable workspace (i.e., 41%) were the most frequently chosen reasons for not having a productive experience. On the other hand, no commuting time to work (i.e., 82%) and a more casual environment at home (i.e., 67%) were among the factors of productivity improvement for those who could cope with working from home well.

5.2. In-store and online shopping

The overall dynamics of shopping expenditures during the COVID-19 pandemic was discussed in Section 4. As people have embraced social distancing to slow down the spread of the coronavirus, we expect to observe a considerable drop-off in the habits of in-store shopping. Due to the importance of this matter, we dedicated a significant part of our analysis to exploring how and to what extent people's shopping behavior has been changing – both the grocery shopping as well as ordering food from restaurants. This section is dedicated to discussing the findings.

The first critical element is to understand what portion of the society had already experienced online shopping, and more importantly, what portion turned to online shopping during the pandemic. Towards this, we asked our respondents to indicate the first time they had such an experience. They had three-time options, which were defined relative to January 24 (i.e., the date that the first confirmed case in Illinois was announced) and March 21 (i.e., the date that the Illinois governor issued the stay-at-home order). Thus, they had three options of 1) before January 24, 2) between January 24 and March 21, and 3) after March 21, 2020. Fig. 14 summarizes

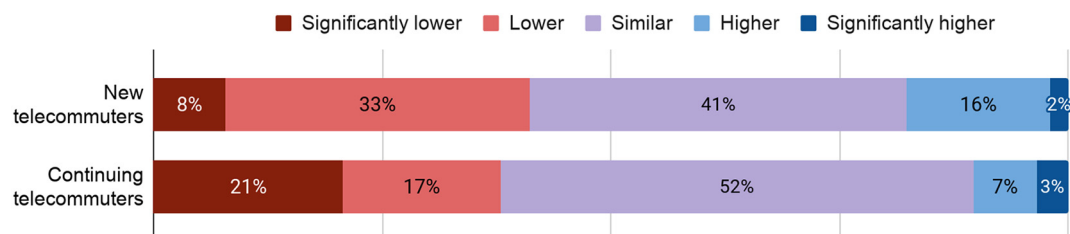


Fig. 12. Workers' self-evaluation of the productivity of working from home *during* the COVID-19 pandemic.

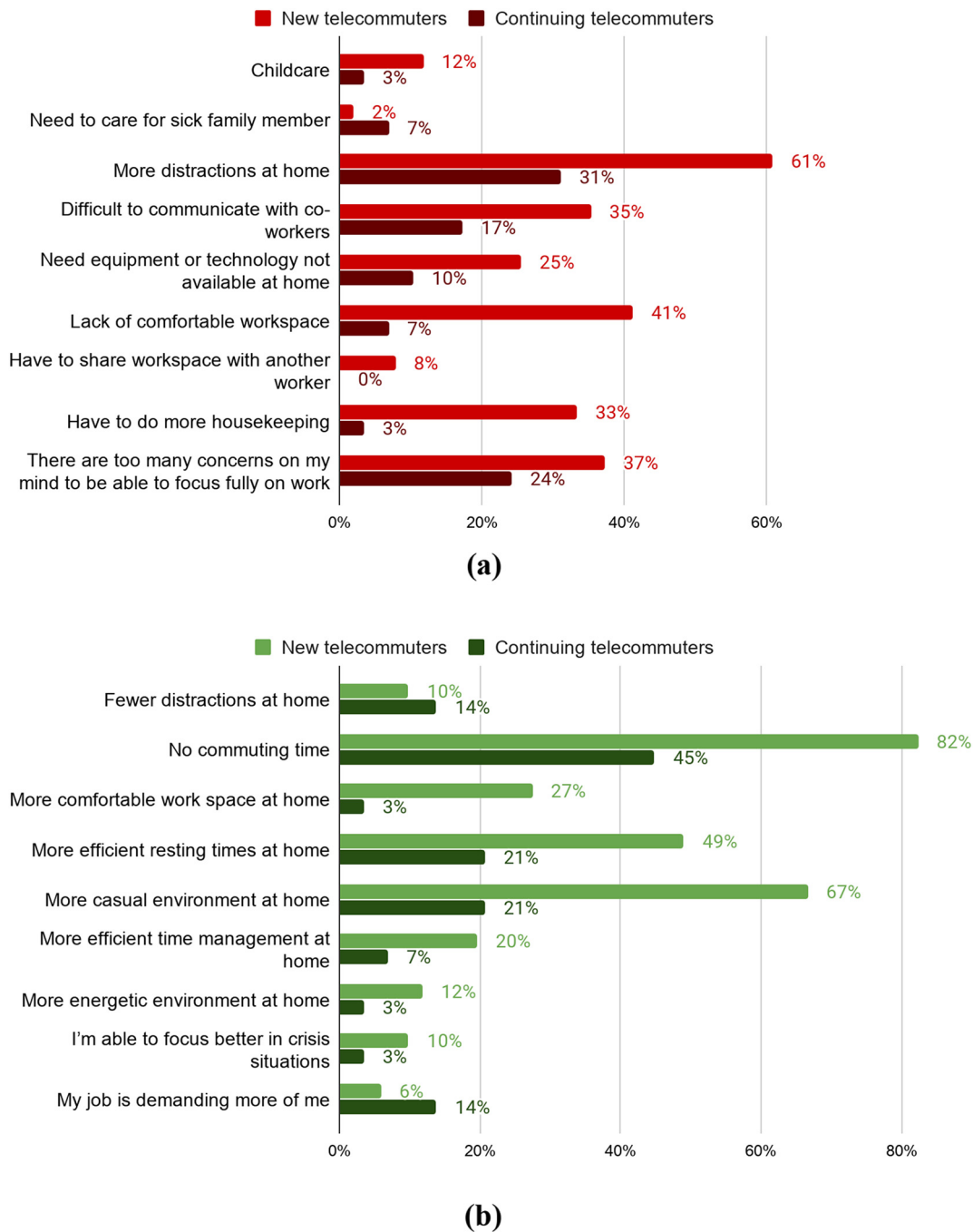


Fig. 13. Reasons for having (a) negative or (b) positive experience with working from home during the COVID-19 pandemic.

the results. As can be seen, about 67% of our respondents never experienced online shopping for groceries before taking our survey. The rest (33%), however, indicated that they had done online shopping for groceries, at least once, before responding to our survey. With regards to online shopping from restaurants, however, we observed that 55% had the experience of using such services before taking the survey.

Getting into more details, 39% (i.e., 6% plus 34%) of those who had experienced online grocery shopping before, indicated that their very first-time online grocery shopping was after January 24, which can be reasonably assumed that it was because of the pandemic restrictions. Moreover, among that 33%, about 60% had experienced online shopping before the pandemic started (i.e., equal to about 20% of the total sample). Therefore, we can conclude that the percentage of those who tried online grocery shopping has increased from 20% to 33% during the past few

months of the pandemic – indicating a 65% growth. A more or less similar increasing pattern was observed for those who used online platforms to order food from restaurants. We observed that the percentage of those who ordered food online has increased from 42% (i.e., the product of 55% and 76%) to 55% – indicating a 31% growth.

The discussions so far focused only on the experience of online shopping for groceries and from restaurants and left the habitual aspect unclear. We also asked two specific questions with regards to the habits of online shopping, one question for grocery shopping and one for ordering food from restaurants. Fig. 15 summarizes the results of these questions. Putting the results of Fig. 14 (a) and Fig. 15 (a) together, we conclude that among the 33% who experienced online grocery shopping at least once, 39% (i.e., 29% plus 10%) identified it as their primary way of meeting their grocery needs during the pandemic. This 39% constitute around 13% of the

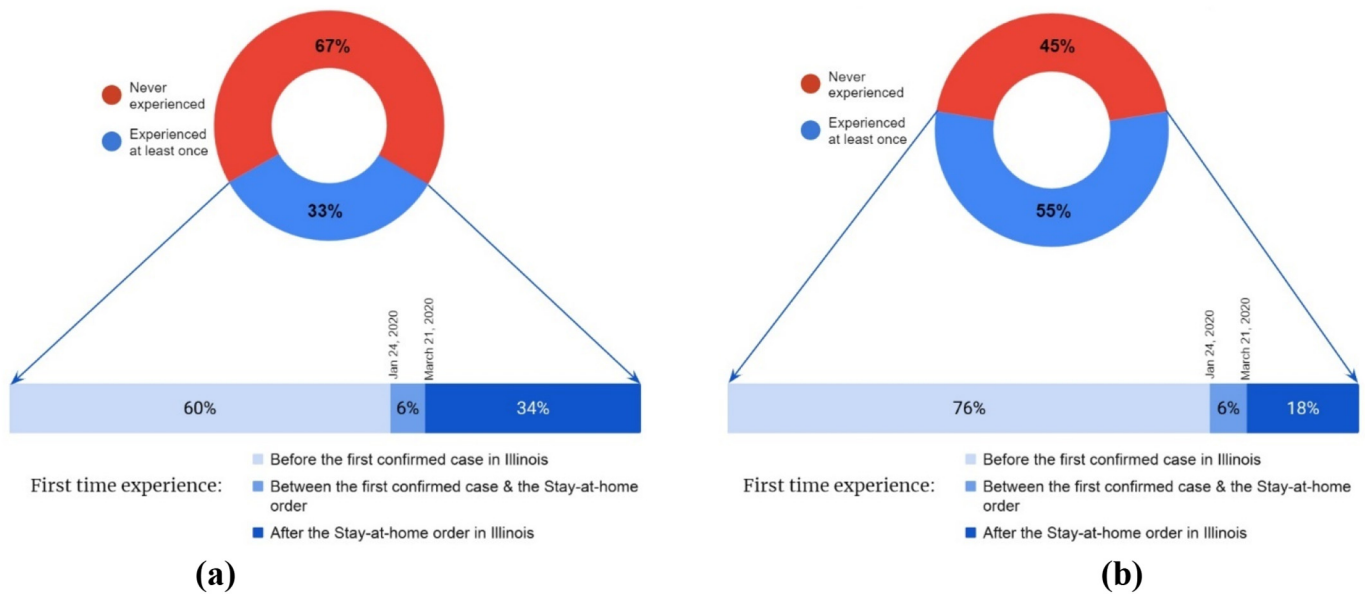


Fig. 14. Sample distribution of the experience of: (a) online grocery shopping, and (b) ordering food online from restaurants.

whole sample (i.e., 39% times 33%), which shows a 550% growth in the proportion of the *habitual* online grocery shoppers (the corresponding statistics was around 2% before the pandemic, i.e., 33% times 7%, which itself is equal to 6% plus 1%). This is while performing the same math to combine the results of Fig. 14 (b) and Fig. 15 (b) indicates a 150% growth in the proportion of *habitual* users of online delivery platforms for ordering food from a restaurant (e.g., Uber Eats and Grubhub).

Comparing the two online shopping categories, therefore, yields the impressive statistics that the growth in habitual behavior of online shopping for groceries has been almost 3.7 times as high as the growth in habits of online shopping for food from restaurants. Furthermore, the results indicate that a significant portion of the society (i.e., 17% of the 33% who experienced online grocery shopping plus the rest 67%, or equivalently 73%) have been still relying mostly (or solely) on in-store shopping for meeting their grocery needs.

Another interesting observation was based on two questions that focused on people's expectations about their future online shopping behavior – each for the short-term and the long run. We asked our respondents to

indicate if it is likely that they will engage in online shopping for groceries and from restaurants more frequently in the future as compared to the before-pandemic time. The results are depicted in Fig. 16. It is very interesting to see that around 74% of our respondents (i.e., 26% plus 25% plus 23%) indicated that they would rely more on online grocery shopping in the first few months after the pandemic compared to the before-pandemic routines. Even more interestingly, around 59% indicated that they would do online grocery shopping more frequently even far after the pandemic. Thus, we conclude that while there will be a slight bounce-back in the long run, people still would be more engaged in online grocery shopping.

A similar pattern has been observed for ordering food from restaurants where 55% of respondents said they would do so more frequently in the short-term future, and 44% said they would do so long after the pandemic. In summary, we can expect that a considerable portion of this notable increase in online shopping for both groceries and meals during the pandemic will sustain in the future.

Understanding the most influential factors on people's preferences towards opting for online shopping over in-store shopping or vice-versa

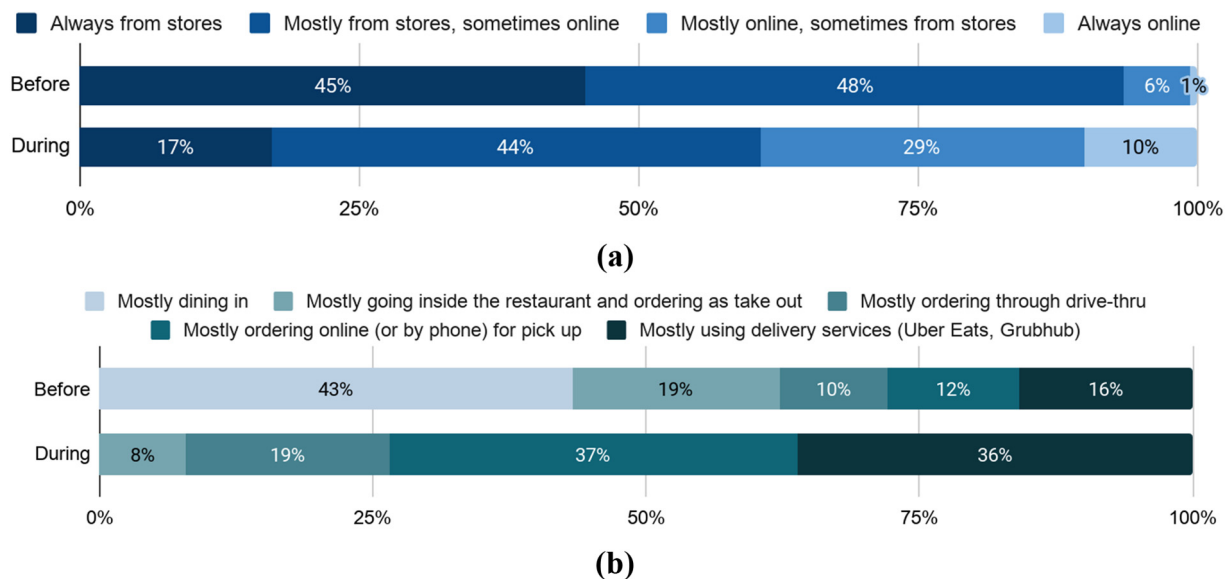


Fig. 15. Sample distribution of the habits of (a) online grocery shopping, and (b) ordering food online from restaurants *before* and *during* the COVID-19 pandemic.

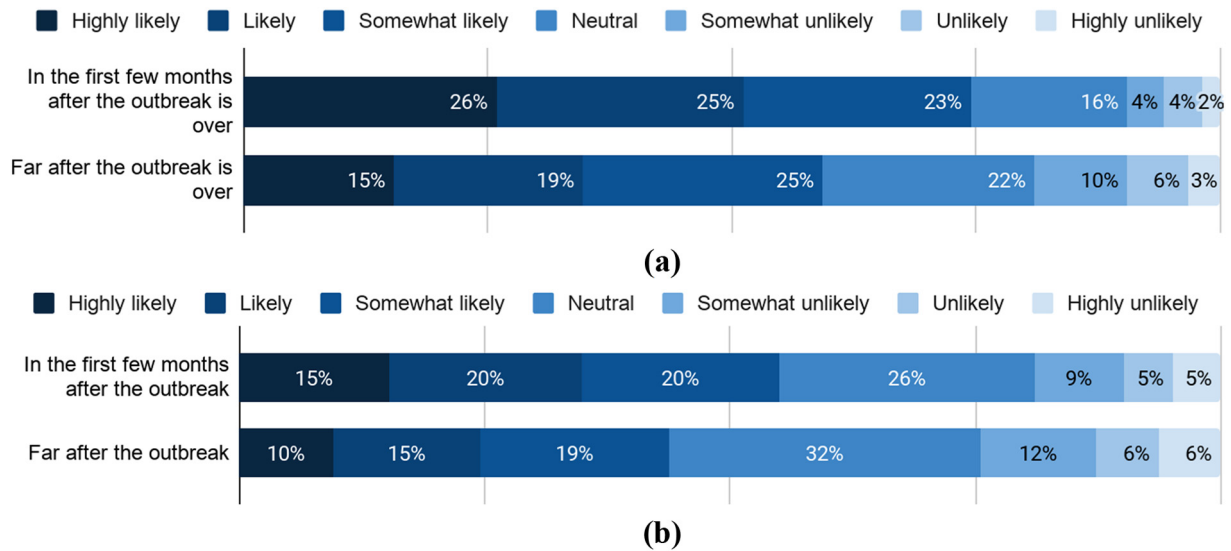


Fig. 16. Sample distribution of how likely the respondents are to do (a) online grocery shopping or (b) ordering food online more frequently in the *future* as compared to the *before-pandemic* routines.

would help the investment and marketing agencies as well as the urban policymakers to better plan for the post-pandemic future. Towards this, we designed a set of questions in which respondents were presented with a list of potential advantages of and concerns about online shopping, and

they were asked to indicate how appealing or concerning each item was for them. To better understand the impact of the pandemic restrictions, these items were asked for both before the pandemic and during the pandemic. Fig. 17 summarizes the results of the pandemic situation and

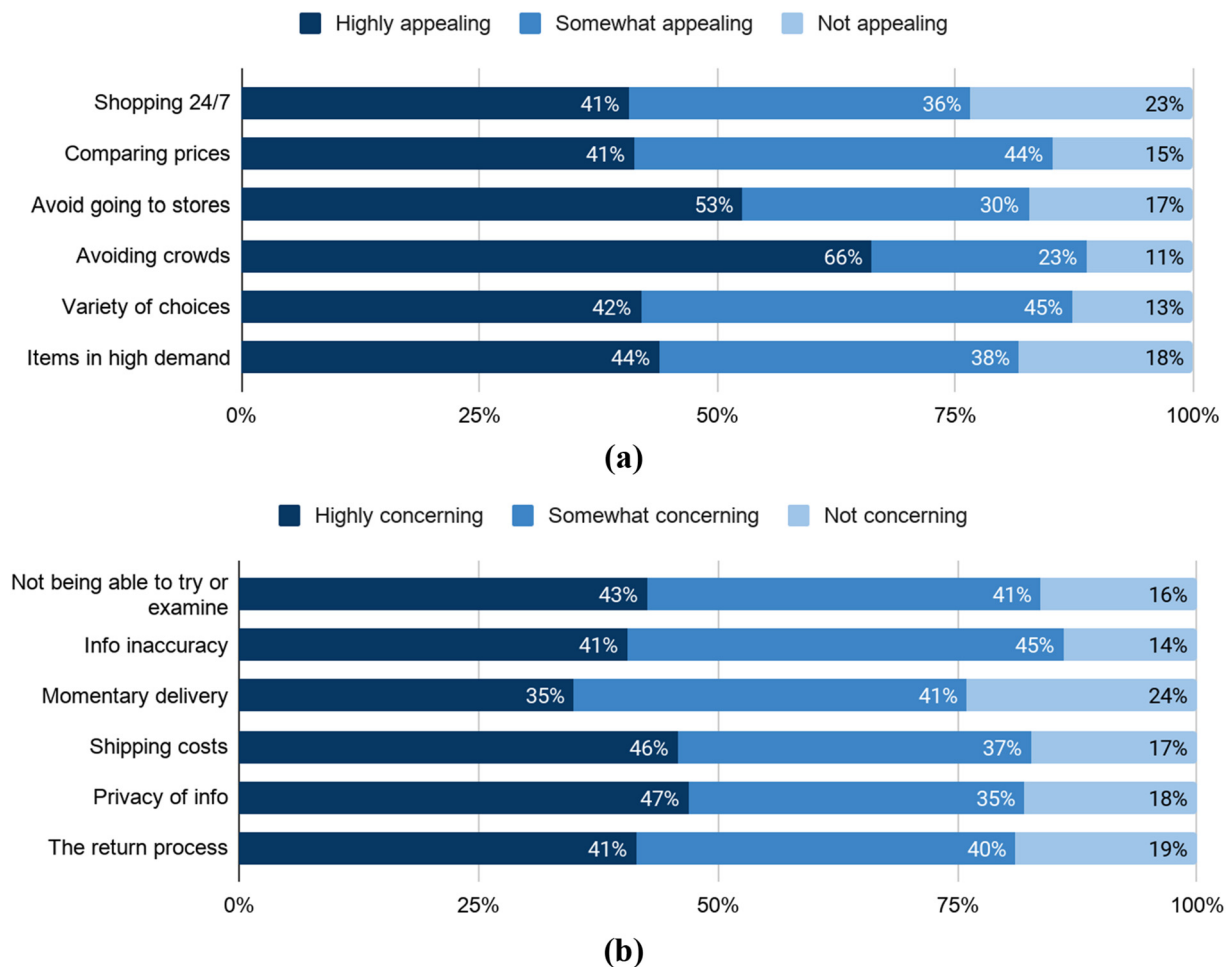


Fig. 17. Sample distribution of perceptions towards (a) positive and (b) negative aspects of online shopping, *during* the COVID-19 pandemic.

Table 1

Observed change in perceptions towards positive aspects of online shopping *during* the COVID-19 pandemic.

Potentially-positive aspects	Change in perceptions towards positive aspects (%)		
	Highly appealing	Somewhat appealing	Not appealing
Shopping 24/7	16.40***	−14.59**	−6.07
Comparing price	−6.30	3.50	7.46
Avoid going to stores	54.15***	−40.36***	−94.94***
Avoiding crowds	40.76***	−79.23***	−81.37***
Variety of choices	−19.01***	18.80***	−4.31
Items in high demand	11.44***	−7.51	−11.98

*** Indicates significance level of 99%.

** Indicates significance level of 95%.

Table 2

Observed change in perceptions towards negative aspects of online shopping *during* the COVID-19 pandemic.

Potentially-negative aspects	Change in perceptions towards negative aspects (%)		
	Highly concerning	Somewhat concerning	Not concerning
Not being able to try or examine	8.72	−6.91	−5.37
Info inaccuracy	14.82**	−4.33**	−28.91**
Momentary delivery	21.88***	−6.93*	−20.00*
Shipping costs	−1.19	−2.67	8.81
Privacy of info	8.86	−5.61	−12.12
The return process	9.50	−7.71	−4.62

*** Indicates significance level of 99%.

** Indicates significance level of 95%.

* Indicates significance level of 90%.

Tables 1 and 2 outline the percentage change in the positive and negative perceptions towards each item from *before*-pandemic to the *during*-pandemic situations.

Among the potentially-positive aspects of online shopping (Fig. 17 (a)), we found that the following factors are the most appealing aspects *during* the pandemic: avoiding crowds and going to public places such as stores, as well as the ability to find high-demand items more easily. Another observation was regarding the changes in perceptions towards appealing reasons (Table 1). Our results showed that, as compared to before the pandemic, people have been putting considerably more emphasis on avoiding crowds, avoiding to go to public places such as stores, and shopping 24/7 during the pandemic, as they have the highest increase in Table 1. On the other hand, with respect to the negative aspects (Fig. 17 (b)), we found that people are more concerned about the possible inaccurate information about the product, the shipping costs, and not being able to try or examine the product before purchasing it. With respect to shifts in concerns (Table 2), we found

that the possibilities of inaccurate information and not having instant access to the item are associated with the most significant increases in being considered as highly concerning.

5.3. Airplane travels

Another important aspect of travel behavior that might change in the future constitutes the higher-level orientations, preferences, and attitudes towards long-distance travels. Airplane travels have long served as the primary mode for long-distance travel that could not be alternatively performed by personal vehicles in a reasonably short period. The recent evidence on the COVID-19 exposure risk factor, however, has made many to re-evaluate their routines to either eliminate some travels—for example, by teleworking—or switch to alternative modes of travel, including personal vehicles. For instance, (Sobieralski, 2020) suggested that airline industries have faced a rapid and severe threats posed by the spread of the novel coronavirus, resulting in a significant job loss. In this sense, how people perceive airplane travels could be considered as a critical predictor of the emerging changes in their long-distance travel behavior. Having this in mind, we designed two questions in our survey to better understand the dynamics of airplane travels in the future.

First, we asked our respondents about how they expect their airplane travels for leisure or personal business to change in the future after the pandemic is over, as compared to their before-pandemic routines. Fig. 18 outlines the results. As can be seen, a considerable portion of the society (i.e., around 43%, which is the sum of 26% and 17%) is expected to travel with airplanes less frequently in the future. Similarly, (de Haas et al., 2020) also reported that Dutch people are expected to significantly reduce their flight frequencies in the future after the pandemic. In addition, we asked those who expected more (or less) airplane travels than before about the reason(s) behind their expectation (multiple choices were allowed). Fig. 19 summarizes the results. It was interesting to see that a significant portion (around 48%) indicated not feeling safe or comfortable with sharing space with others. The next highest portion (27%) corresponded to shifting towards personal vehicles. Among the other reasons that negatively affect airplane travels, we can also refer to the financial and affordability issues (25%).

5.4. Risk perceptions

In previous sections, we discussed the dynamics of travel behavior in terms of a variety of aspects, including working from home, online shopping, mode choice, and airplane travels. A factor that underlies many of these aspects is how people perceive the risk of exposure to the virus. This section is dedicated to exploring the perception of people towards the exposure risk given a variety of travel choices.

Fig. 20 summarizes the perceived risk of using various travel modes. According to the results, personal vehicles turned out to be associated with the lowest perceived risk of exposure. Ranked after personal vehicles, biking with private bicycles and walking are found to have the second- and

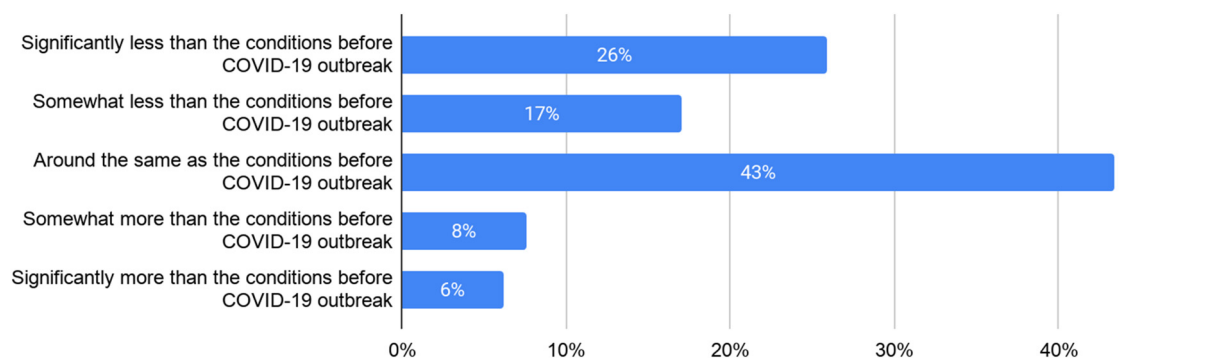


Fig. 18. Expected change in airplane travels once the COVID-19 is no longer a threat as compared to the *before*-pandemic situations.

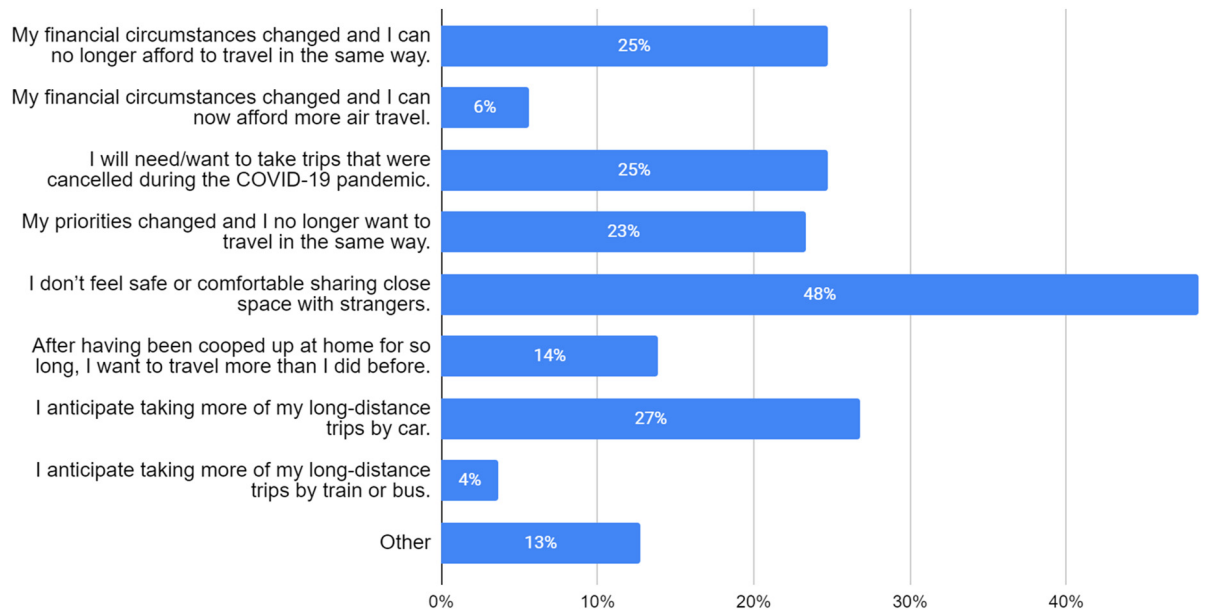


Fig. 19. Factors underlying the expected change in airplane travels once the COVID-19 is no longer a threat as compared to the *before*-pandemic situations.

third-lowest perceived risks of exposure – respectively, 29% and 23% categorized as medium to high risk of exposure. This shows the notable role of active transportation and micro-mobility during the pandemics in preventing the users of transit, taxi, and ride-hailing services from switching to personal vehicles. Similarly, (Teixeira and Lopes, 2020) found evidence on a possible modal shift from the subway to the bike sharing system in New York, U.S.

Furthermore, transit, taxi and ride-hailing services (e.g., UberX), as well as pooled ride-hailing (e.g., Uberpool) are the first three highest risky modes in people's view. Around 93% of the respondents indicated that they associate transit with medium to extremely high risk of exposure to the novel coronavirus. This finding is in line with (Bucsky, 2020) who observed that usage of public transit decreased dramatically by 80%, while the overall mobility was reduced maximally by 64%. However, out of this 93% portion, more than 26% either reported that their household owns no personal vehicles or someone else in their household is the main driver of the vehicles owned. Moreover, around 14% were found to be senior citizens older than 65 (who probably have difficulty substituting transit with active modes), over 13% are from lower income households (i.e., annual income of \$50 K or less) who neither own a bike nor have a bike-sharing membership. As mentioned in Section 3, we collected the nearest intersection to the home address of the respondents via Google Maps API. Linking

this information to the Smart Locations database (cite), we also noticed that over 24% out of the 93% portion of the observations belong to those who live in low pedestrian-oriented neighborhoods (i.e., where the density of pedestrian-oriented facilities is lower than the 25th percentile).

These results, collectively, shed light on the importance of pro-actively planning for a more “equitable” future transportation system to minimize the disparities in accessibility among various socio-demographic groups and residents of various urban settings. Explaining the sensitivity of the demand for using transit, Taxis and, ride-hailing services to the pandemics, the results also highlight the need to expand the concept of “resiliency” beyond its current domain of service disruptions (A. Rahimi et al., 2020; E. Rahimi et al., 2020; Rahimi et al., 2019). The recent pandemic experiences showed us that there should also be a longer-term aspect to “resiliency of the transportation systems” to focus on the resiliency during the prolonged pandemics.

In addition to the risk of using various modes of transportation, we also included a question asking about the perceived risk of visiting various locations and participating in various activities during the pandemic. The results are summarized in Fig. 21. The results indicated that the risk of indoor activities is generally considered to be more than outdoor activities. Interestingly, also, going to gyms or fitness centers are found to be almost as risky as going to the hospitals in people's view—around 91% of the

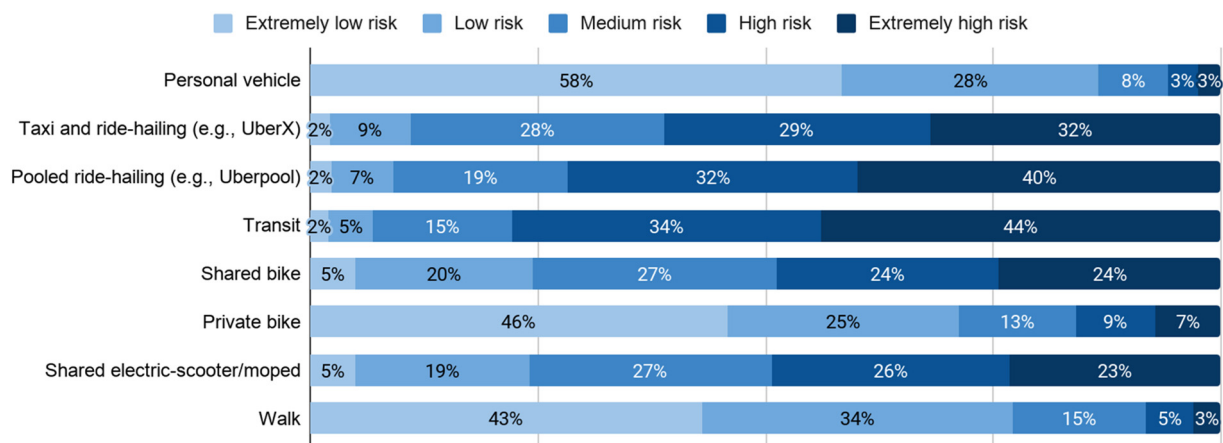


Fig. 20. Perceived risk of traveling with different modes during the COVID-19 pandemic.

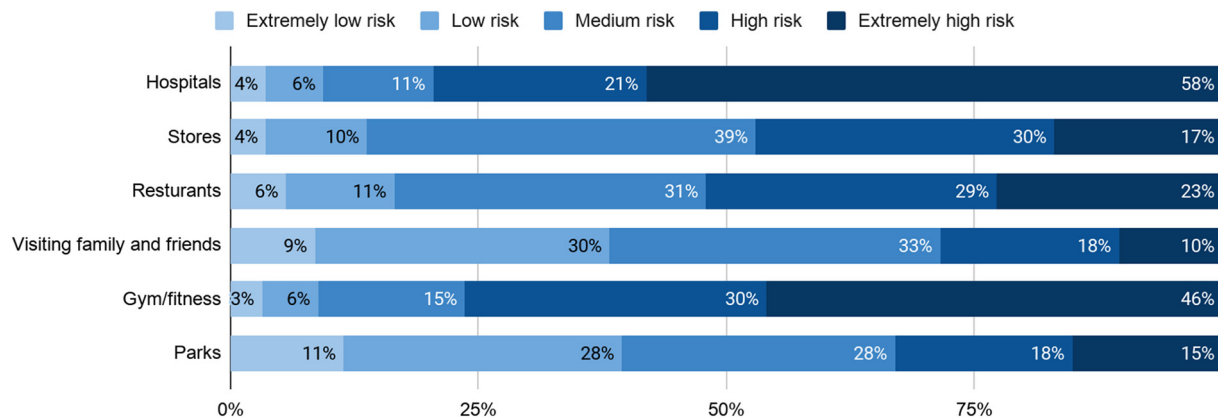


Fig. 21. Perceived risk of visiting different locations during the COVID-19 pandemic.

respondents associated medium to extremely high risk of exposure to these activities. In-store shopping and restaurants stand at the second and third ranks, respectively, with 86% and 83% categorizing as a medium to extremely high-risk activity.

6. Policy implementations & future insights

The previous sections discussed the dynamics of various aspects of activity-travel behavior and perceptions impacted by the COVID-19 pandemic, and this section seeks to put the results into perspective for transportation planning and offer insights for future research.

The first theme that emerged from our results pertains to the productivity of working from home and its association to individuals' perceptions towards their home environment. The results suggest that working from home carries high potential for moving towards a more sustainable future. The underlying literature supports the significant influence of policies to promote telecommuting on alleviate traffic congestion and improving air quality (Shabanpour et al., 2018). As a practical way of influencing the workers' preferences, the results of this study point to the significant role of their productivity while working from home. According to results described in Section 5.1, although the “new telecommuters” in our sample evaluate their productivity in various ways, the “workability of their home environment” is a common theme in their evaluations. The two most reported reasons for a negative productivity were distractions in the home environment, and lack of a comfortable working environment at home. At the same time, two of the first three most common reasons behind positive work productivity levels at home are also related to the home environment. That is, those who work from home are significantly more productive if their home-office provides comfortable and energetic workspaces, with opportunities for restful breaks and minimal disruptions.

These results suggest that “home workability” is a critical factor for consideration in future research regarding work productivity levels in the home environment. From a different perspective, the results also suggest potential shifts in peoples' perceptions towards residential location choice given that several businesses and companies have been allowing employees to work from home—even permanently in some cases. Therefore, our results also point towards “home workability” as a critical factor to be considered in future research that pertains to residential location preferences.

The second theme that emerged from the results pertains to shared mobility and active transportation. They suggest a potential shift from usage of shared mobility options such as pooled ridesharing and transit services to modes that avoid contact—such as walking, biking, using scooters, and personal vehicles. The results in Section 5.4 show that a notable portion of the society associates transit and pooled ride-sharing services with medium to extremely high exposure risks, and thus opt to use other modes as safer alternatives. An important implication that can be made from this observation is that active transportation and micro-mobility modes can play substantial roles in planning towards more sustainable and resilient cities.

Promoting mobility-styles and habitual travel behaviors centered around active transportation and micro-mobility options not only paves the way towards a more sustainable future but also improves the resiliency of our cities in limiting person-to-person contact during infectious disease outbreaks such as the COVID-19 pandemic.

The third theme emerging from the results relates to the concept of “equity”. Per the results, while a significant portion of respondents associated a high risk of exposure to the virus while using public transit, not all of them have access to alternative modes of transportation. They may not have access to a personal vehicle or live in areas with sufficient pedestrian-oriented facilities or biking infrastructure. This finding highlights the importance of equity when designing multi-modal transportation systems, and how this importance becomes even more apparent during crises like the COVID-19 pandemic. An equitable transportation system can reduce disparities in accessibility among residents of a region across various socio-economic backgrounds, helping to promote safe and convenient access to opportunities such as jobs and healthcare. The importance of equitable transportation systems that maximizes distribution levels and access across the whole service area is especially important when considering the context of Chicago. The Chicago metropolitan area displays a sizable level of economic and demographic diversity, as well as persisting issues in racial segregation, posing challenges in ensuring transportation equity across the region. These results also point towards an ever more car-reliant society in the post-pandemic era, given the personal sense of safety and non-contact nature that comes with personal vehicles. Nonetheless, the overall lesson to be gleaned from these results is the need for proactive transportation planning in a way that promotes an active and equitable transportation system.

Additionally, the current COVID-19 experience showed us how inequitable certain policies such as the stay-at-home order could be for various member of society based on their job categories—especially for low-income households, and part-time workers. In Section 4, we observed that the percentage of workers with an annual household income of less than \$30 K that became unemployed due to the pandemic for the first few months was four times as high as the corresponding statistics for high-income households (annual income of \$150 K or more). Indeed, our analyses highlight the need for more equitable approaches to implementing work restriction guidelines in future pandemic situations.

The fourth theme of the policy implications relates to the efficacy of such policies as the stay-at-home order and the closure of non-essential businesses in moving towards the social distancing goals. We observed a considerably high proportion of workers in essential business (i.e., around 37%) which potentially puts a cap on the efficacy of governmental orders to close non-essential businesses. Our observations also yielded a more or less similar finding with regards to the shopping trips for groceries and meals, which put a cap on the efficacy of the stay-at-home order. As shown in Section 5.2, despite the notable growth in online shopping for

groceries, a significant portion of the society still relies on in-store shopping as their primary choice in meeting grocery needs.

These observations along with the equity issues related to such policies (as discussed above), shed light on the importance of pro-actively planning for the future pandemics, by designing comprehensive decision support systems which can guide the future policies towards being more equitable and efficient. To improve the efficacy and equitability of such policies, they could be designed based on complex combinations of a range of strategies including proper adjustments of the operating hours of various essential businesses. As a comprehensive decision support system, we suggest agent-based models c, due to the highly complex and dynamic nature of the policy evaluation needs. The dynamic and modular design of the algorithmic core of ADAPTS (Auld and Mohammadian, 2009; Shamshirpour et al., 2019) makes it a flexible tool that can be proficiently adjusted to incorporate changes in people's activity-travel behavior during the pandemic situations.

The last, but not the least, key takeaway in the aftermath of COVID-19 pertains to the future autonomous vehicles (AVs). As discussed in Section 5.3, another notable shift in travel behavior is from airplanes as a mode for travel for leisure or personal business trips to car road trips. As a result of this shift, people may be more apt to adopt AVs in the future since such vehicles are geared towards facilitating long-distance travel by eliminating the need to continually pay attention to the task of driving, and enables riders to make better use of their travel time. As with the expected shift away from transit and ride-hailing services (i.e., due to avoidance of crowds), we also expect that promoting shared AVs (SAVs) and pooled SAVs (PSAVs) over privately-owned AVs will become more challenging in the future (Azimi et al., 2020; Lavieri and Bhat, 2019; A. Rahimi et al., 2020; E. Rahimi et al., 2020), which could potentially pose serious sustainability challenges for our AV-dominated future cities. As suggested by (Levin et al., 2017), domination of privately-owned AVs over PSAVs could result in heightened traffic congestion levels. Furthermore, we can expect an increase in the adoption rate of larger body sizes (e.g., AVs in the form of recreational vehicles or vans), since they provide a more comfortable road trip experience.

7. Conclusion

The COVID-19 pandemic has caused many to re-examine their habits and priorities, and thereby, brought considerable changes to how people perform their everyday tasks. The present research has set out to shed light on the dynamics of people's mobility-styles—including habits, predispositions, and higher-level orientations towards tele-activities (i.e., online shopping, online business meetings and working from home, etc.) and travels (i.e., long-distance commutes and urban travel mode choice) during and after the COVID-19 pandemic.

This research's framework is designed as a longitudinal analysis with multiple survey waves to monitor the activity-travel dynamics continually. The present article reports on the preliminary results of the first wave (i.e., conducted from April 25, 2020, to June 2, 2020) which was dedicated to the Chicago metropolitan area. Focusing on the overall behavioral trends caused by the COVID-19 pandemic, the discussions in this article provide essential insights for planners and policymakers to better prepare for the post-pandemic era. The details of the survey and the results of our analyses are discussed in Sections 3 to 5. Furthermore, a detailed description of the insights into the future of our cities and suggested directions for future research is discussed in Section 6.

The future insights provided in Section 6 includes suggestions that consider various aspects of planning towards the resident-centric smart cities, including the work-related productivity of the agents, equitable and smart governance, as well as sustainability and resiliency of the transportation system. The suggested research directions includes: 1) conceptualization of a "home workability" index and inclusion in the future modeling efforts concentrating on residential location analyses, as well as multitasking and work-related productivity; 2) expansion of the current domain of the concept of "transportation system resiliency" to include longer-term aspects such as resiliency in pandemic situations; and 3) researching potential

avenues to promote sustainable and safe modes of travel to prevent further car-dependency.

As a limitation of the discussions in this article, the presented analyses are mostly geared towards identifying the overall behavioral trends, while relying on the future research for more detailed, individual-level analyses. As such, we call for future research to go beyond the aggregate-level trends presented in this article and focus more on the individual-level behaviors. This necessity becomes apparent specially with respect to the need for updating the current activity-travel agent-based simulation frameworks like ADAPTS to serve as flexible decision support systems. The future research should pay especial attention on identification of the underlying temporal and spatial variations, among other confounding factors.

CRedit authorship contribution statement

The authors confirm contribution to the paper as follows: study conception and design: A. Shamshirpour, E. Rahimi, R. Shabanpour, A. Mohammadian; data collection: A. Shamshirpour, E. Rahimi, R. Shabanpour, A. Mohammadian; analysis and interpretation of results: A. Shamshirpour, E. Rahimi, R. Shabanpour, A. Mohammadian; draft manuscript preparation: A. Shamshirpour, E. Rahimi, R. Shabanpour. All authors reviewed the results and approved the final version of the manuscript.

Declaration of competing interest

The authors do not have any conflicts of interest to declare.

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