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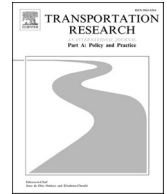
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Impact and analysis of rider comfort in shared modes during the COVID-19 pandemic

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ABSTRACT

Travel behavior has dramatically shifted during the COVID-19 pandemic as social distancing measures and stay-at-home orders are encouraged to prevent the spread of infection. Shared mobility, which includes transit, ride-hailing, and shared ride-hailing, typically involves contact with strangers and is now viewed as a potential risk. To understand current trends and predict potential modal shifts in a post-COVID-19 world, this research designed, developed, and deployed a short online survey about comfort with and usage of shared transportation. The survey was distributed through multiple recruitment methods to adults in the Atlanta metro area. Data collected from the survey ($n = 787$) revealed preferences related to ride-sharing environments and safety procedures, frequency of travel on different modes before and during the pandemic, and level of comfort related to the usage of different modes. Despite reopening the economy in Georgia, this research found that the actual usage of private ride-hailing and transit has dramatically decreased. In addition to the usage, the indicated comfort level with usage of shared mobility has decreased since the pandemic. Looking to the future, regression models and data analysis indicated that although there would be an increase in comfort for all shared modes when a vaccine is available, it does not return to the pre-pandemic levels.

1. Introduction

The novel coronavirus (COVID-19) pandemic dramatically impacted the way people around the world work, socialize, and travel. The virus responsible for COVID-19, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is most commonly spread between people who are in close contact with one another as it moves through respiratory droplets (CDC 2020). To reduce potential exposure, individuals around the world would choose to work from home, only leave for essential trips, and travel with as little contact with strangers as possible. Crises and other network disruptions, like the current pandemic and associated social distancing trends, can result in long-lasting changes in travel behavior and travel demand including modal switches and changes to travel frequency (Goodwin, 1977). Attitudes and activity patterns changed as many transportation options were considered unsafe or unavailable. In particular, shared mobility saw a significant decrease in usage as the COVID-19 risk has reduced people's willingness to share a ride (Beck & Hensher, 2020) (Bucsky, 2020) (Shamshiripour, 2020). Shared mobility, which includes bike-sharing, carsharing, public transit, paratransit, and ride-sourcing services such as Uber and Lyft, involves multiple users sharing services and resources concurrently or one after another (NASEM, 2020). Prior to the pandemic, shared mobility was associated with many positive benefits including reduced traffic congestion, lower greenhouse gas emissions, and smaller parking demand. To receive these benefits, we must

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understand the mechanisms linking travel to one another and their willingness to share the ride. The post-COVID period often referred to as the “new normal”, may reflect several scenarios including shared mobility options returning to business as usual, becoming less attractive compared to private travel options, or disappearing completely (Shaheen, 2020) (Hensher, 2020). The longer-term impacts of the pandemic on shared mobility are still unknown.

To gain insight on the impacts of COVID-19 on shared mobility, we developed an online reported-revealed preference survey to measure the comfort and usage of users on three types of shared mobility, private ride-hailing, shared ride-hailing, and public transit, during the periods before, during, and after the COVID-19 pandemic. As Georgia was one of the first U.S. states to reopen, the Atlanta metro area provides a useful sample population to provide insight into the future. The collected data explains changes in shared mobility usage due to varying levels of willingness-to-share before and during the pandemic. Little is known about how changes in shared mobility comfort may persist in a post-pandemic future. This research bridges gaps in knowledge related to COVID-19 and shared mobility so transportation policy and plans can best reflect changes in the “new normal”.

2. Background

2.1. Response to the COVID-19 pandemic in Georgia

After COVID-19 was declared a national emergency in the U.S. on March 13, 2020, the state of Georgia declared a state public health emergency on March 14, requiring all public schools, colleges, and universities to close. To curb the spread of the virus, Georgia implemented a shelter-in-place order, a ban on gatherings over 10 people, and the closure of bars and nightclubs on March 23, 2020. The Metropolitan Atlanta Rapid Transit Authority (MARTA), the primary public transportation operator in the Atlanta metro area, reduced rail and bus operations, removed bus fares, and implemented rear-door boarding on March 30 in response to the pandemic. Georgia was one of the first states to reopen in the U.S. On May 1, Georgia’s shelter-in-place order for the public expired allowing businesses and restaurants to re-open with capacity limits. Bars and nightclubs in Georgia would begin to re-open in June. Amid a local surge in the virus in mid-July, Atlanta’s mayor signed an order requiring masks to be worn in businesses. Fig. 1 displays the new positive cases, hospitalizations, and deaths associated with COVID-19 over time in Georgia. After peaking in mid-August, COVID cases were on the decline in Georgia until mid-October (Georgia Tech, 2020). As of December 2020, the public health state of emergency, social distancing guidelines, and local option face-covering requirements are still in effect in Georgia (Georgia.gov, 2020). MARTA resumed normal front-door boarding and fare collection on September 7, 2020, and resumed rail and bus operations in April 2021 (MARTA, 2020 & MARTA, 2021).

In addition to MARTA, other shared mobility services reduced or suspended services during phases of the pandemic in Atlanta. Micromobility e-scooter services including Bird and Uber’s JUMP were suspended from April to July. Nationwide, shared ride-hailing services including UberPool and Lyft Shared were suspended indefinitely on March 17. For the first few months of the pandemic, TNCs encouraged people to only use ride-hailing services for essential trips. In May 2020, Uber and Lyft outlined measures and precautions for ride-hailing services including passenger limits, face mask requirements for drivers and passengers, a requirement for passengers to ride in the back seat, encouragement of air circulation with rolled down windows, and a vehicle cleaning guide. During the pandemic, ride-hailing services continued efforts to reduce risk by introducing contact tracing and by distributing additional masks and sanitizing products.

2.2. Impact of COVID-19 pandemic on shared mobility

A growing number of studies have examined the impact of COVID-19 on transportation behaviors during the pandemic. During the early months of the pandemic, March and April, the number of trips for all modes significantly dropped (Dutzik, 2020) (Bucsky, 2020)

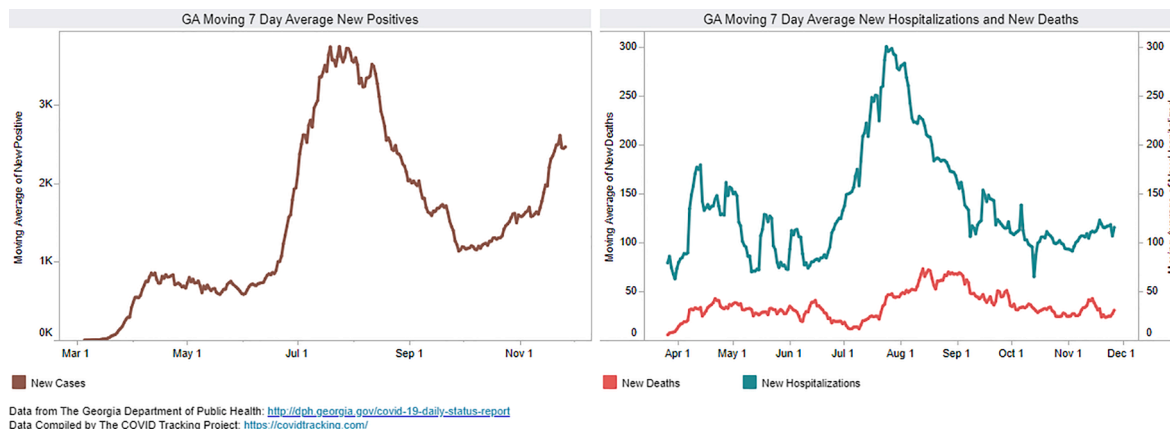


Fig. 1. Key indicators of COVID-19 levels in GA (Georgia COVID-19, 2020).

(De Haas, 2020). In addition to examining actual usage, customer attitudes indicated a significant drop in usage of public transit and ridesharing apps and services (IBM, 2020). These early trends and predictions motivated further research into the potential long-term impacts on behaviors and preferences. A survey in April 2020 found that 39 % of those who previously used ride-sharing, and 45 % of those who previously used public transportation, expected they would decrease or stop their use when economic activity resumes (CarGurus 2020). As the pandemic continued into the summer, two research studies attempted to examine the current and future impact of COVID-19 on transportation behavior by collecting survey data across the U.S from April to June (Conway 2020) (Beck et al., 2020) (Shamshiripour, 2020). Major current and future trends from these studies include an increase in work from home and a potential shift from shared mobility options such as pooled ridesharing and transit services. The decrease in usage of transit, pooled ride-hailing, and ride-hailing during the pandemic is likely due to the high perceived risk from these travel modes (Shamshiripour, 2020). While the majority of survey respondents expected their use of various modes in the “new normal” to return to levels before the pandemic, a significant minority expected a change likely due to new work-from-home options (Conway, 2020). A large survey collection effort related to transportation behavior and COVID-19 occurred in July and August 2020 (CUTR, 2020). Similar to previous surveys, a large majority of respondents (more than 60 %) expressed some skepticism in their use of shared transportation modes such as public transit, shared ride-hailing, and private ride-hailing during the pandemic. This trend of skepticism in shared mobility was predicted to continue even once the COVID-19 pandemic is no longer a threat.

As conditions surrounding the pandemic continue to change through the fall 2020 and winter 2021, this study aimed to enhance the literature on mobility preference during the continuing pandemic and identify potential trends in the post-pandemic world. This paper presents some initial findings from the reported preference survey data. The goal of this research was to examine the comfort and usage of shared mobility before, during, and after the pandemic to provide a better understanding of the potential future impacts of COVID-19. The rich data set will be used in models and further analysis in future work.

3. Data and methodology

To assess the reported and revealed preferences of transportation users in the Atlanta area, a brief online survey was designed and developed to be completed in 10 min or less with five short sections. The length of the survey was mindful of participant time to more likely result in a high response rate. The first set of questions collected participants’ level of comfort on different shared modes during three time periods: the period before COVID-19, the current time when they completed the survey, and a future period when a COVID-19 vaccine is available. A definition of each shared mode was included in this section to familiarize participants with the terms used in the survey. After indicating their level of comfort on a Likert-scale, the survey included a series of Likert-scale general attitude statements and opinion statements related to existing COVID-19 procedures in transit and ride-hailing. The third and fourth sections were designed to collect frequencies of trip usage for different modes in a typical time before the COVID-19 pandemic and in the past month during the COVID-19 pandemic. The fourth section included an attention check which screened out invalid responses from the data set based on the knowledge that shared ride-hailing services were suspended during the pandemic. Therefore, if a respondent indicated that they had used shared ride-hailing services in the past month during the pandemic, they were removed from the data. The survey concluded with common demographic questions to collect background information about each respondent including age, race, gender, education, income, and employment status.

3.1. Data collection

The data was collected through the use of an online survey hosted by the Qualtrics platform. Data collection began on October 14, 2020, and concluded on November 18, 2020; a follow-on data collection effort was planned for a future period when the COVID-19 vaccine is widely available. This data collection period was chosen due to the relative stability of virus cases and established routines in a post-COVID world. Before the data collection period, new reported COVID-19 cases in the metro Atlanta area had peaked and were on the decline until mid-October. During the period of data collection, the Atlanta metro area had a slight increase in new COVID-19 cases but no change in restrictions. Additionally, COVID-19 vaccines were still in developmental phases, but many were optimistic about upcoming vaccines by the end of October. Data reporting the effectiveness of COVID vaccines was released in mid-November 2020 and the FDA issued emergency use authorization in December 2020.

Survey data was collected through multiple online recruitment channels from adults in the Atlanta metro area. A detailed description of the advantages and disadvantages of each recruitment methodology is explored in a future paper. Our mixed sampling approach includes participants recruited through the following five survey methods:

- a) *Online opinion panel service (N = 384)*: A commercial online opinion panel was used to recruit and verify a specific number of guaranteed and timely responses. A total number of 384 valid surveys included in the data set were recruited through this channel.
- b) *Email recontact of respondents from transportation surveys (N = 211)*: A total of 1447 email survey requests were sent to the email addresses provided by willing respondents in previous transportation studies. Of the email recontacts, 1185 were from a two-wave bicyclist preferences survey that targeted Westside, Eastside, Grant Park, and South Atlanta neighborhoods in 2017 and 2019 (Clark, 2019). The other 262 email recontacts were from an intercept survey of MARTA riders after the I-85 road closure in 2017. A total of 211 valid respondents completed the survey through this channel (14.6 % valid response rate). The low response rate is possibly due to the large gap in time between survey requests and the lack of monetary incentive.
- c) *Neighborhood newsletters and platforms (N = 132)*: Survey distribution requests were sent to 58 neighborhood planning units and neighborhood organizations in the metro-Atlanta area. Twelve organizations agreed to share the survey within their community

through online newsletters, email groups, and/or social media like Facebook and Nextdoor. This effort resulted in a total of 132 valid survey responses completed through this channel.

- d) *Facebook advertisements (N = 46)*: A Facebook advertisement campaign linking directly to the survey ran during the full data collection period. The audience for this campaign included adults in the Atlanta area. The campaign, which included visual media ads and call-to-action text linking directly to the survey site, generated 565 unique link clicks and ultimately resulted in 90 completed surveys. Only 46 of these attempts were valid responses included in the data. This low valid response rate (8.1 %) is possibly due to the lack of monetary incentive for respondents and survey length expectations.
- e) *Task distribution platform (N = 14)*: Mechanical Turk (MTurk) is a task distribution platform where requesters post simple paid tasks such as surveys, to recruit respondents. Over the data collection period, the survey task was published twelve times. To participate in the survey task and receive the \$2 incentive upon completion, MTurk-registered workers who lived in Georgia had to answer a screener question to specify that they live or work in the Atlanta area. This recruitment channel only resulted in 14 valid responses. This low response volume may be due to the limited number of Atlanta residents active on the platform.

3.2. Data description

The data collection process resulted in a sample of 787 complete and valid surveys. The sample over-represents highly-educated, high-income, middle-aged, and white populations. Table 1 compares the survey results with the ACS demographic estimates of the Atlanta population.

A further breakdown of the demographic categories used in the models can be found in Table 2. Age and income are further broken down into different groupings, which indicate a large percentage of the sample (40.0 %) is Gen X, 41–55 yrs. old. The frequencies of trip usage for different modes before the pandemic were used to identify non-users, occasional users, and active users for ride-hailing, shared ride-hailing, and transit. Non-users indicated that they “Never” used the mode before the pandemic, occasional users indicated that they used the mode “1–3 times a month” or “less than once a month”, and active users indicated that they used the mode at least once a week. The majority of respondents that use transit and private ride-hailing are occasional users (56.8 % and 66.1 %). Active shared ride-hailing users only account for a small share of respondents (7.8 %) and are mainly represented by Millennials (25–40 yrs. old) and Gen Z (18–24 yrs. old) participants. Almost half of the respondents (49.6 %) had never used shared ride-hailing. A multimodal lifestyle binomial variable was determined by the usage of a bicycle, shared e-scooter, transit, or ride-hailing at least once a week. Multimodal respondents make up 35.7 % of the sample.

The survey included two questions asking the participant’s employment situation before and during the pandemic. These answers were compared and a binomial variable indicated an employment change resulting in less work or study. The majority of the sample before and during the pandemic only worked (79.0 % and 72.9 %). The pandemic resulted in an employment situation with less work or studying for 7.9 % of the respondents.

3.2.1. Personal attitude and opinion results

Participants responded to 23 attitudinal and opinion statements on a five-point Likert-scale from “Strongly Disagree” to “Strongly Agree”. These statements were designed so that several related statements would pertain to a single construct for future factor analysis.

Table 1
Distribution of Demographics for Survey Respondents.

		Responses (N = 787)	% of Respondents	% of Atlanta Population*
Household Income	Less than \$25,000	67	8.7 %	14.7 %
	\$25,00 - \$49,999	112	14.1 %	19.2 %
	\$50,00 - \$74,999	110	14.2 %	18.2 %
	\$75,00 - \$99,999	100	12.7 %	13.2 %
	\$100,000 - \$149,999	174	22.1 %	16.8 %
	More than \$150,000	223	28.2 %	17.8 %
Gender	Female	429	54.4 %	51.7 %
	Male	355	45.2 %	48.3 %
	Prefer to Self-Describe	3	0.4 %	NA
Respondent Age	18–34	211	26.8 %	31.8 %
	35–49	332	42.2 %	27.8 %
	50–64	172	21.9 %	24.8 %
	65+	72	9.1 %	16.7 %
Race/Ethnicity**	White / Caucasian	568	71.4 %	45.9 %
	Black / African American	175	22 %	34.2 %
	Hispanic / Latino	38	4.8 %	11.0 %
	American Indian / Native American	12	1.5 %	0.2 %
	Asian / Pacific Islander	41	5.2 %	6.1 %
	Other	25	3.1 %	2.7 %
Education	Lower than bachelor’s degree	157	19.9 %	60.1 %
	Bachelor’s degree or higher	630	80.1 %	39.9 %

* From 2019 ACS estimates.

** Respondents were allowed to mark more than one (sum of percentages may exceed 100%).

Table 2
Additional Demographics and Lifestyle Indicators.

		Responses (N = 787)	% of Respondents
Generation	Gen Z (18–24 yrs. old)	52	6.6 %
	Millennial (25–40 yrs. old)	257	32.7 %
	Gen X (41–55 yrs. old)	315	40.0 %
	Boomer (56–74 yrs. old)	153	19.4 %
	Silent (75 + yrs. old)	10	1.3 %
Lower than \$50 K Income		179	22.8 %
Higher than \$100 K Income		397	50.40 %
Private Ride-Hailing Use (Pre-COVID-19)	Non-User	107	13.6 %
	Occasional User	520	66.1 %
	Active User	160	20.3 %
Shared Ride-Hailing Use (Pre-COVID-19)	Non-User	390	49.6 %
	Occasional User	336	42.6 %
	Active User	61	7.8 %
Transit Use (Pre-COVID-19)	Non-User	178	22.6 %
	Occasional User	447	56.8 %
	Active User	162	20.6 %
Multimodal Lifestyle Employment (Pre-COVID)		281	35.7 %
	Does not work or study	98	12.5 %
	Only studies	45	5.7 %
	Only works	622	79.0 %
	Works and studies	22	2.8 %
Employment (Current)	Does not work or study	150	19.1 %
	Only studies	41	5.2 %
	Only works	571	72.9 %
	Works and studies	22	2.8 %
Employment change resulting in less work or study		62	7.9 %

A selection of these questions (coded from 1 = Strongly Disagree to 5 = Strongly Agree) are displayed in [Table 3](#). Attitudinal statements reveal that the majority of the sample consider themselves to be sociable (82.5 %), would choose to work from home if given the option (67.2 %), miss small interactions with strangers (61.0 %), and always carry hand sanitizer (58.6 %).

Existing COVID-19 protocol on public transit includes requiring drivers to wear masks, encouraging passengers to wear masks and social distance, and providing frequent cleaning and sanitizing of stations and vehicles. We asked respondents their opinion on these procedures through Likert-scale opinion statements and found the average respondents supported most protocols, as seen in [Table 4](#). The majority of respondents (95.4 %) agreed that wearing a mask should be required for all passengers riding public transit. The majority of respondents (67.9 %) would have felt uncomfortable due to potential COVID-19 risk if someone sat next to them on a MARTA bus or train, even if they were wearing a mask. Almost half (46.0 %) of respondents trusted the precautions and extra effort taken by MARTA transit to clean and sanitize. To balance the extra resources dedicated to COVID-19 procedures in transit and reduce risk, some bus routes have been suspended. This response from transit agencies did not reflect the opinion of respondents as the majority of respondents (68.6 %) disagreed that transit services should be suspended until a vaccine for COVID-19 is found.

COVID-19 protocols on ride-hailing vehicles included the suspension of pooled services, requiring passengers and drivers to wear masks, opening the window if applicable, and providing passengers with extra sanitation options. We asked respondents their opinion on these procedures through Likert-scale opinion statements and found the average respondent supported these as seen in [Table 5](#). Almost half of the respondents (43.4 %) agreed that shared ride-hailing services should be suspended until a vaccine for COVID-19 is found. The majority of respondents (73.7 %) agreed that if their ride-hailing driver wasn't wearing a mask, they would request a new vehicle. The majority of respondents (78.6 %) agreed that opening the windows while riding on a ride-hailing vehicle is worth the

Table 3
Response to Selected Personal Attitude and Opinion Questions (n = 787).

	Mean	S.D.	Median
If I could commute and go into work, I would go to my office.	2.79	1.26	3
If I could work from home and not commute, I would work from home.	3.83	1.20	4
I travel more now simply to “get out” instead of traveling for a reason.	2.87	1.29	3
I enjoy chatting with fellow passengers in a shared ride-hailing vehicle.	2.89	1.11	3
I wear headphones while in a ridesharing vehicle to avoid interactions.	2.45	1.21	2
I enjoy chatting with my ride-hailing driver.	3.33	1.09	3
I miss small interactions with strangers.	3.59	1.09	4
I always carry hand sanitizer.	3.47	1.33	4
I'm uncomfortable being around people I don't know.	3.04	1.13	3
My friends and family would describe me as “germ conscious”.	3.33	1.08	3
I consider myself to be a sociable person.	4.11	0.86	4

1 = Strongly Disagree, 2 = Disagree, 3 = Neither Disagree or Agree, 4 = Agree, 5 = Strongly Agree.

Table 4
Response to Selected Transit COVID-19 Measures Questions (n = 787).

	Mean	S.D.	Median
Transit services should be suspended until a vaccine for COVID-19 is found.	2.25	1.15	2
I trust the precautions and extra effort taken by MARTA transit to clean and sanitize.	3.34	1.07	3
Opening the windows while riding on public transit is worth the discomfort.	3.92	1.00	4
If someone wearing a mask sat next to me on MARTA, I would feel uncomfortable.	3.76	1.15	4
Wearing a mask should be required for all passengers riding public transit.	4.78	0.61	5

1 = Strongly Disagree, 2 = Disagree, 3 = Neither Disagree or Agree, 4 = Agree, 5 = Strongly Agree.

Table 5
Response to Selected Ride-Hailing COVID-19 Measures Questions (n = 787).

	Mean	S.D.	Median
Opening the windows while riding in a ride-hailing vehicle is worth the discomfort as it reduces the risk of COVID-19.	4.10	0.99	4
If my ride-hailing driver wasn't wearing a mask, I would request a new vehicle.	3.99	1.06	4
I would feel comfortable riding with a stranger in a shared ride-hailing vehicle as long as there is a seat in between passengers.	2.53	1.25	2
Shared ride-hailing with strangers services should be suspended until a vaccine for COVID-19 is found.	3.13	1.25	3
I would feel comfortable using a ride-hailing vehicle if I was equipped with disinfectant sprays and wipes to sanitize the vehicle before and after each ride	3.37	1.20	4

1 = Strongly Disagree, 2 = Disagree, 3 = Neither Disagree or Agree, 4 = Agree, 5 = Strongly Agree.

discomfort as it reduces the risk of COVID-19. Half of the respondents (53.4 %) agreed that they would feel comfortable using a ride-hailing vehicle if they were equipped with disinfectant sprays and wipes to sanitize the vehicle before and after each ride.

The attitudinal and opinion questions in the second section of the survey were designed to be able to use several items to form aspects of a single construct. A set of underlying factors can explain the interrelationships among observed attitude and opinion variables. To construct the underlying factors, a Kaiser-Mayer-Olkin (KMO) measure was used to check the sampling adequacy. The data resulted in KMO statistics equal to 0.701 showing that factor analysis could be performed on the attitude and opinion data. The data from these sections considered 18 five-point Likert-scale ordinal variables. Because the variables were in the ordinal form, a polychoric correlation was performed. The varimax orthogonal rotation technique, which was applied to maximize the variance of squared factor loadings, was used to improve interpretability. Exploratory factor analysis solutions with 3 to 6 factors were considered. Items with weak loadings and poor interpretability were considered for removal. The final (rotated) factor loading matrix is presented in Table 6 with factor loadings (values higher than 0.3 are shown and values higher than 0.6 are in bold). As seen in Table 6, the factor analysis yields a four-factor solution which explained 55.54 % of the variance. The four identified factors based on the loadings are explained below:

- *Follow Safety Measures*: The four variables positively relate to wearing masks and improving air circulation in shared mobility modes form this factor.
- *Extrovert*: Four variables related to positively interacting with other people combine to form this factor.

Table 6
Factor Loading Matrix of 4 Factors on 14 Items.

	<i>Follow Safety Measure</i>	<i>Extrovert</i>	<i>Trust Precautions</i>	<i>Germophobe</i>
Opening the windows while riding on public transit is worth the discomfort as it reduces the risk of COVID-19.	0.771			
If my ride-hailing driver wasn't wearing a mask, I would request a new vehicle.	0.733			
Opening the windows while riding in a ride-hailing vehicle is worth the discomfort as it reduces the risk of COVID-19.	0.726			
Wearing a mask should be required for all passengers riding public transit.	0.646			
I enjoy chatting with my ride-hailing driver.		0.807		
I enjoy chatting with fellow passengers in a shared ride-hailing vehicle (e.g. UberPool).		0.721		
I miss small interactions with strangers.		0.717		
I consider myself to be a sociable person.		0.608		
I would feel comfortable riding in a shared ride-hailing vehicle as long as there is a seat in between passengers.			0.818	
I would feel comfortable using a ride-hailing vehicle if I was equipped with disinfectant sprays and wipes to sanitize the vehicle before and after each ride.			0.697	
I trust the precautions and extra effort taken by MARTA transit to clean and sanitize.			0.667	
I always carry hand sanitizer.				0.783
My friends and family would describe me as "germ conscious".				0.762
If someone wearing a mask sat next to me on a bus or train, I would feel uncomfortable due to COVID-19 risk.			-0.353	0.408

- *Trust Precautions*: Three variables relate to the comfort and trust of shared mobility COVID precautions.
- *Germophobe*: Three variables relate to the awareness of germs spreading.

3.2.2. *Usage of Ride-Hailing, shared Ride-Hailing, and transit results*

In addition to reported preferences, the survey examined revealed preference data by collecting the actual ridership frequency for each shared mobility mode before and during the COVID-19 pandemic. Two sets of survey questions (one before the pandemic and one in the past month during the pandemic) asked respondents to select a usage frequency category for each mode:

- *Never (1)*
- *Less than once a month (2)*
- *1–3 times a month (3)*
- *1–2 times a week (4)*
- *3–4 times a week (5)*
- *5 or more times a week (6)*

In addition to shared mobility modes, the survey asked for usage of typical mode choices and technologies that replace trips. Each coded choice before and during the pandemic, seen in Table 7, was converted to an approximate monthly frequency and subtracted to determine the change in usage. The average monthly frequency usage of all modes decreased during the pandemic, with the largest change occurring in personal vehicles. Of the shared modes, the monthly frequency usage decreased the most in rail transit and private ride-hailing. The most common modes used among respondents before and during the pandemic were their personal vehicles and walking. During the pandemic, 27.7 % respondents switched to teleworking five or more times a week, with the highest average change in monthly usage frequency of technologies during the pandemic.

As seen in Fig. 2, each mode of transportation had a larger decrease than increase in usage frequency. MARTA rail and private ridesharing had the largest percentage of respondents decrease in usage frequency. The frequency of usage of walking and private vehicle usage increased during the pandemic. These findings are limited due to the small sample of respondents actively using the other shared modes. To account for the large number of shared mobility non-users in the sample, Table 8 further breaks down the change in usage frequency by “user type”. Private ride-hailing and transit saw the largest decrease in shared mobility usage in the time between the pandemic and during the pandemic. Occasional and active users of shared modes reported mostly decreases in modal usage while most non-users did not change their shared mode usage. A small portion of the sample increased usage of transit and private ride-hailing. A small portion of the respondents (4 % of occasional users) reported an increase in usage frequency of transit. A small portion (4 %) of occasional and active users of private ride-hailing users also reported increases in frequency of modal usage.

To understand the reason behind the change in transit and shared ride-hailing usage, follow-up questions were asked, as displayed in Table 9. Of the 263 respondents that indicated a change in usage of transit, 188 (71.5 %) agreed that the change is due to a change in transit service. The most common reason for change in transit service included bus routes no longer in service (31.4 %) and bus routes with less frequent service (26.1 %). Almost half (50.4 %) of respondents that indicated a change in usage of shared ride-hailing (n = 397) agree that it was because shared ride-hailing was unavailable.

3.2.3. *Level of comfort using Ride-hailing, shared Ride-Hailing, and transit results*

To understand changes in comfort levels using different modes of transportation throughout the pandemic, respondents were asked three questions about private ride-hailing, shared ride-hailing with strangers, and public transit for each specified period:

- “Before COVID-19, I would have felt comfortable using...”
- “With the current COVID-19 risk, I would feel comfortable using ...”

Table 7
Frequency of Mode Usage Before the COVID-19 Pandemic and During the Pandemic (n = 787).

	Mean			S.D.		
	Before	October 2020	Change	Before	October 2020	Change
Personal Vehicle (alone)	16.51	12.11	-4.40	10.05	9.65	9.73
Personal Vehicle (with others)	8.54	5.02	-3.52	8.47	6.87	7.32
Private Ride-hailing	2.84	0.89	-1.95	4.68	3.03	4.46
Shared Ride-hailing	1.18	0.05	-1.13	3.15	0.16	3.11
MARTA Bus	2.05	0.68	-1.37	5.36	3.22	4.89
MARTA Rail	3.14	0.77	-2.37	6.56	3.16	5.95
Personal Bike	2.60	2.10	-0.50	6.03	5.35	4.31
Shared Bike	0.41	0.31	-0.10	2.08	1.91	2.31
Shared Scooter	0.42	0.30	-0.12	1.90	1.83	2.02
Walk	11.06	9.96	-1.10	10.23	9.73	7.23
Teleworking	3.80	10.94	7.14	7.18	11.28	10.66
Online Shopping	5.17	7.02	1.85	6.55	7.43	6.09
Food Delivery	3.06	4.36	1.30	5.45	6.41	5.09
Video Chat	3.70	7.96	4.26	6.84	8.76	7.00

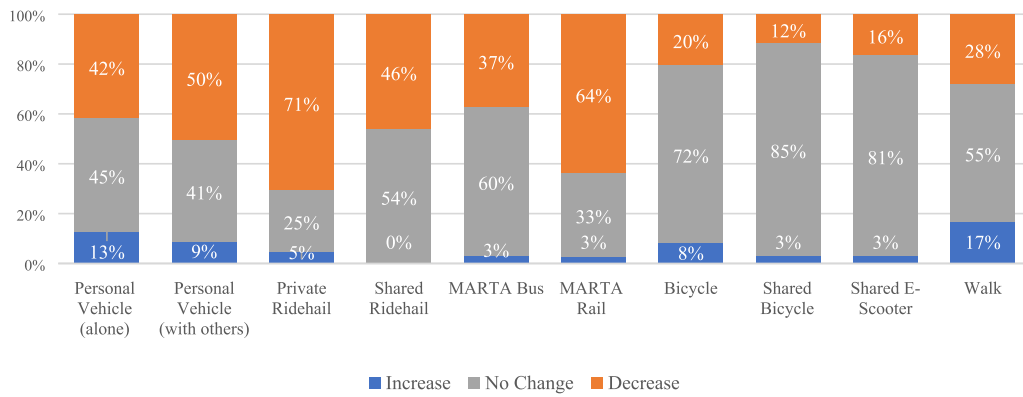


Fig. 2. Change in Usage Frequency (Before the Pandemic to October 2020) for Each Mode (n = 787).

Table 8

Changes in Usage of Ride-hailing, Shared Ride-Hailing, Transit (Before to During Pandemic).

Private Ride-Hailing	Non-User (n = 107)	Occasional User (n = 520)	Active User (n = 160)	Total (n = 787)
Decreasing	0 (0 %)	222 (43 %)	138 (86 %)	360 (46 %)
No Change	104 (97 %)	275 (53 %)	16 (10 %)	395 (50 %)
Increasing	3 (3 %)	23 (4 %)	6 (4 %)	32 (4 %)
Shared Ride-Hailing	Non-User (n = 390)	Occasional User (n = 336)	Active User (n = 61)	Total (n = 787)
Decreasing	0 (0 %)	336 (100 %)	61 (100 %)	397 (50 %)
No Change	390 (100 %)	(0 %)	0 (0 %)	390 (50 %)
Increasing	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)
Transit	Non-User (n = 178)	Occasional User (n = 447)	Active User (n = 162)	Total (n = 787)
Decreasing	0 (0 %)	106 (24 %)	139 (86 %)	245 (31 %)
No Change	178 (100 %)	323 (72 %)	23 (14 %)	524 (67 %)
Increasing	0 (0 %)	18 (4 %)	0 (0 %)	18 (2 %)

Table 9

Reason Explaining Change in Transit and Shared Ride-Hailing Usage.

	Frequency	Percentage
I have changed the way I travel because my typical transit service has changed;	188	23.9 %
My bus route is no longer in service.	59	31.4 %*
My bus route has more frequent service.	26	13.8 %*
My bus route has less frequent service.	49	26.1 %*
My rail service has less frequent service.	28	14.9 %*
I traveled more on the bus because it was free.	26	13.8 %*
I have changed the way I travel because shared ride-hailing is not available.	162	20.6 %

* Percentage of users that changed the way they travel because their typical transit had changed (n = 188). (Respondents were allowed to select more than one reason).

- “In the future when a COVID-19 vaccine is available, I will feel comfortable using...”

To capture the comfort level of share mobility after the pandemic, a future period was defined as the time when a vaccine is available. As the definition of the time “after the pandemic” could vary among individuals (e.g. when positive cases have been significantly reduced, when most restrictions have been lifted, when a “cure” is introduced...) a fixed future period was selected to increase specificity and represent an attainable, forthcoming “new normal” period. A Despite the inclusion of a fixed future period in the survey, a gap between the reported and real preferences may exist due to limitations when self-reporting preferences; respondents may not remember their past behavior or may not be capable of predicting their behavior in a future hypothetical scenario. For each shared mode and period, respondents indicated their level of comfort with a 5-point Likert-scale from “Strongly Agree” to “Strongly Disagree”, as displayed in Fig. 3.

The majority of respondents indicated that they felt comfortable using ride-hailing (89.3 % agreed or strongly agreed), transit (79.8 %), and shared ride-hailing (58.7 %) before the pandemic. Shared ride-hailing services had the lowest level of comfort with only 28.2 % of respondents strongly agreeing that they would feel comfortable using the service before COVID-19. Assuming the October 2020 risk of COVID-19, the majority of respondents would not feel comfortable using shared ride-hailing (80.0 %) and transit (65.4 %). Only 46.4 % of respondents indicated that they would feel uncomfortable in October 2020 using private ride-hailing while almost an equal

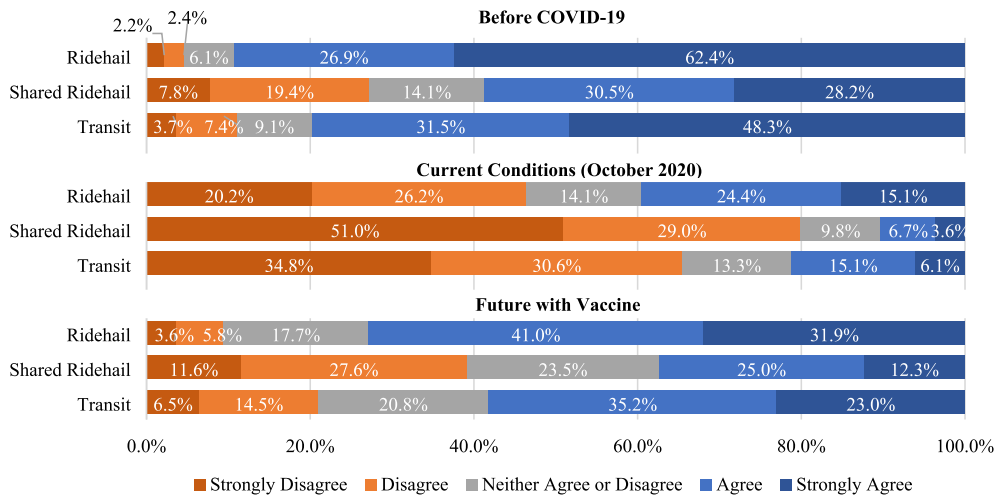


Fig. 3. Distribution of Agreement to Statement “Before COVID-19, I would have felt comfortable using...” for Private Ride-Hailing, Shared Ride-Hailing, and Public Transit (n = 787).

amount of respondents indicated that they would feel comfortable using the mode (39.5 %). When a vaccine is available, a majority of respondents indicated that they would feel comfortable using ride-hailing (72.3 %) and transit (58.2 %).

Assigning a number from 1 to 5 for each category of the Likert scale (1 = Strongly Disagree to 5 = Strongly Agree), we can examine the ordinal data, displayed in Tables 10a-10c. A value closer to 5 indicates a strong level of comfort and a value closer to 1 represents a low level of comfort. These tables also display results from paired two-sample t-tests with unequal variances which were performed to confirm the mean difference between the sets of data observation (before to current, before to future, and current to future) is zero. This indicates that potential users did have a change in the level of comfort between all periods. In the future when a vaccine is available, the general sample indicated that ride-hailing and transit reported levels of comfort will return to similar (but slightly lower) levels when compared to pre-COVID-19 levels; Both private ride-hailing and transit resulted in a difference in average comfort of approximately -0.5). During the pandemic, a negative change in reported comfort was most drastic in transit; before the pandemic, respondents regardless of usage indicated a high level of comfort using transit (mode = 5) but during the pandemic, the level of comfort using transit dramatically decreased (mode = 1).

3.2.4. Change in level of comfort using Ride-hailing, shared Ride-hailing, and transit results

Examining the frequency of changes in reported comfort between periods, as seen in Table 11, we can see a significant decrease in comfort for all modes between the current period and before the pandemic. Respondents indicated that their level of comfort will increase for all modes when comparing the current and future comfort levels. This indicates their current level of comfort using shared mobility is lower than it was before the pandemic and will increase in the future after the pandemic. Comparing the reported level of comfort in the periods before and after the pandemic, most respondents indicated no change or a decrease in comfort across all modes. If this trend of lower reported level of comfort in shared modes persists, the future may not return to the same level as the time before the pandemic for an extended period of time.

Table 10a
Frequency of Reported Comfort Level of Private Ride-Hailing.

Comfort Using Private Ride-Hail		Total (n = 787)	Non-User (n = 107)	Occasional User (n = 520)	Active User (n = 160)
Mode	Before	5	4	5	5
	Current	2	1	2	4
	Future	4	3	4	5
Mean	Before	4.45	3.54	4.59	4.59
	Current	2.88	2.52	2.86	3.18
	Future	3.92	3.21	3.97	4.20
Variance	Before	0.774	1.552	0.485	0.570
	Current	1.907	1.780	1.811	2.149
	Future	1.044	1.552	0.866	0.891
p-value	Before -> Current	0.000***	0.000***	0.000***	0.000***
	Current -> Future	0.000***	0.000***	0.000***	0.000***
	Before -> Future	0.000***	0.009**	0.000***	0.000***

*** p-value < 0.001, ** p-value < 0.01, * p-value < 0.05.

1 = Strongly Disagree, 2 = Disagree, 3 = Neither Disagree or Agree, 4 = Agree, 5 = Strongly Agree.

Table 10b
Frequency of Reported Comfort Level of Shared Ride-Hailing.

Comfort Using Shared Ride-Hail		Total (n = 787)	Non-User (n = 390)	Occasional User (n = 336)	Active User (n = 61)
Mode	<i>Before</i>	4	2	5	5
	<i>Current</i>	1	1	1	2
	<i>Future</i>	2	2	4	4
Mean	<i>Before</i>	3.52	2.87	4.13	4.26
	<i>Current</i>	1.83	1.63	1.99	2.20
	<i>Future</i>	2.99	2.53	3.40	3.63
Variance	<i>Before</i>	1.669	1.630	0.896	0.963
	<i>Current</i>	1.169	0.876	1.397	1.294
	<i>Future</i>	1.483	1.252	1.268	1.505
p-value	<i>Before -> Current</i>	0.000***	0.000***	0.000***	0.000***
	<i>Current -> Future</i>	0.000***	0.000***	0.000***	0.000***
	<i>Before -> Future</i>	0.000***	0.000***	0.000***	0.001**

*** p-value < 0.001, ** p-value < 0.01, * p-value < 0.05.

1 = Strongly Disagree, 2 = Disagree, 3 = Neither Disagree or Agree, 4 = Agree, 5 = Strongly Agree.

Table 10c
Frequency of Comfort Level Using Transit.

Comfort Using Transit		Total (n = 787)	Non-User (n = 178)	Occasional User (n = 447)	Active User (n = 162)
Mode	<i>Before</i>	5	5	5	5
	<i>Current</i>	1	1	1	2
	<i>Future</i>	4	4	4	4
Mean	<i>Before</i>	4.13	4.38	4.36	4.5
	<i>Current</i>	2.27	2.24	2.34	2.57
	<i>Future</i>	3.54	3.81	3.75	3.85
Variance	<i>Before</i>	1.184	0.715	0.757	0.786
	<i>Current</i>	1.564	1.476	1.573	1.539
	<i>Future</i>	1.389	1.015	1.094	1.249
p-value	<i>Before -> Current</i>	0.000***	0.000***	0.000***	0.000***
	<i>Current -> Future</i>	0.000***	0.000***	0.000***	0.000***
	<i>Before -> Future</i>	0.000***	0.000***	0.000***	0.000***

*** p-value < 0.001, ** p-value < 0.01, * p-value < 0.05.

1 = Strongly Disagree, 2 = Disagree, 3 = Neither Disagree or Agree, 4 = Agree, 5 = Strongly Agree.

Table 11
Frequency of Changes in Comfort Between Time Periods.

Change in Reported Comfort		Decrease		No Change		Increase	
Before to Current (n = 787)	Private Ride-hail	540	68.6 %	209	26.6 %	38	4.8 %
	Shared Ride-hail	568	72.2 %	190	24.1 %	29	3.7 %
	Transit	612	77.8 %	150	19.1 %	25	3.2 %
Current to Future (n = 787)	Private Ride-hail	52	6.6 %	268	34.1 %	467	59.3 %
	Shared Ride-hail	30	3.8 %	234	29.7 %	523	66.5 %
	Transit	30	3.8 %	216	27.4 %	541	68.7 %
Before to Future (n = 787)	Private Ride-hail	336	42.7 %	401	51.0 %	50	6.4 %
	Shared Ride-hail	313	39.8 %	386	49.0 %	88	11.2 %
	Transit	355	45.1 %	369	46.9 %	63	8.0 %

Individual shifts in level of reported comfort were calculated between periods for each mode. The distribution of change in comfort ranges from -4 to 4 as displayed in Fig. 4. Mainly negative changes occur at the start of the pandemic, positive changes occur as the pandemic continues, and no changes occurs long-term due to the pandemic. It is important to note that the same change in comfort can result from two different starting points.

3.3. Shared mobility comfort models methodological approach

An objective of this study was to investigate how factors of individuals' willingness to share mobility was impacted by the COVID-19 pandemic. Ordinal logit, mixed logit model, and latent class models were explored to understand the relationship between explanatory variables on the level of comfort using shared mobility during three periods during the pandemic. Ultimately, ordered

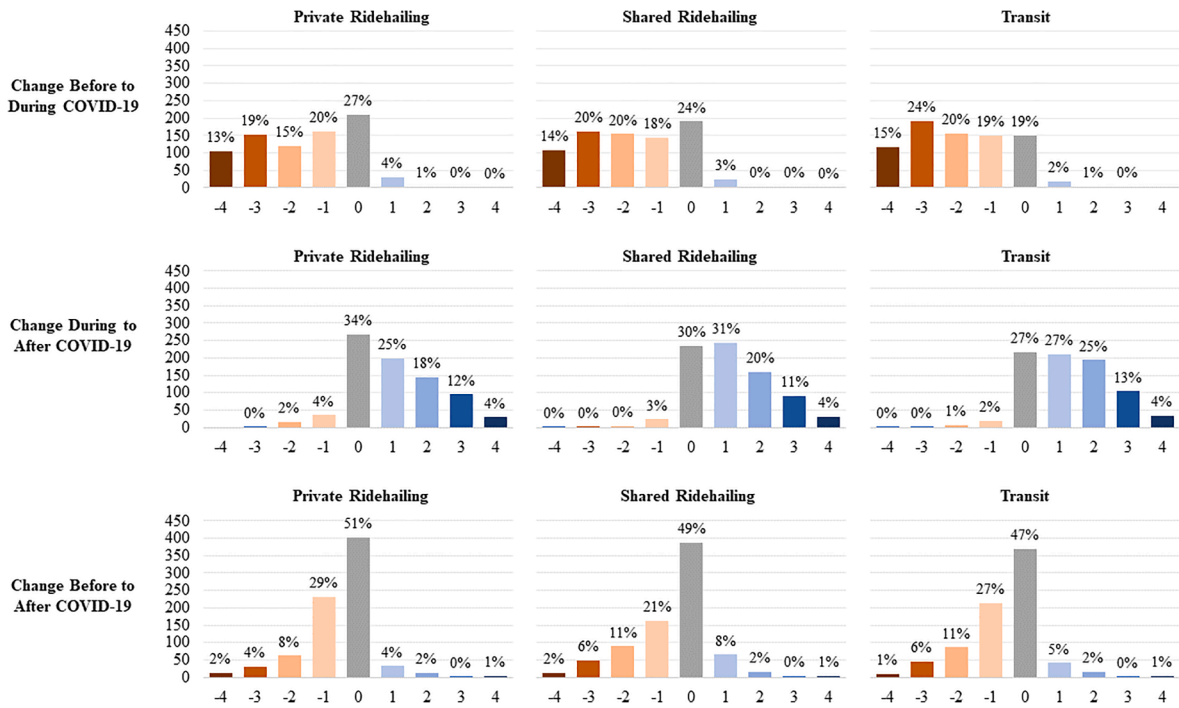


Fig. 4. Distribution of change of level of comfort for ride-hailing, shared ride-hailing, and transit (n = 787).

logit models predicting the reported level of comfort in private ride-hailing, shared ride-hailing, and transit were estimated for each period (before the pandemic, October 2020 during the pandemic, and a hypothetical future with a vaccine). Independent variables in the models included loaded attitude factors calculated from the factor analysis, socio-demographic binomial and numeric variables, and prior modal usage binomial variables across different modes. As the dependent variables was Likert-type data with an intuitive order (1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, and 5 = Strongly Agree), the use of an ordered modeling approach was most appropriate (Greene and Hensher, 2008). The observed ordinal data (y_i) was defined by an unobservable variable (z_i) and estimable thresholds (α), and coded as:

$$y_i = 1 \text{ if } z_i \leq \alpha_1$$

$$y_i = 2 \text{ if } \alpha_1 < z_i \leq \alpha_2$$

$$y_i = 3 \text{ if } \alpha_2 < z_i \leq \alpha_3$$

$$y_i = 4 \text{ if } \alpha_3 < z_i \leq \alpha_4$$

$$y_i = 5 \text{ if } z_i > \alpha_4$$

The resulting regression model had the traditional structure,

$$z_i = \beta X_i + \varepsilon_i$$

where β is a vector of the coefficients, x_i are the independent variables and ε_i is the error term. The probability of an individual with a comfort level j was given by:

$$P(Y_i > j) = \frac{\exp(\alpha_j + X_i\beta)}{1 + [\exp(\alpha_j + X_i\beta)]}, j = 1, 2, 3, 4$$

This model follows the assumption of parallel regression for ordinal logistic regression and was validated through the results of the Brant Test (Williams 2006). Model fit was evaluated and reported by McFadden pseudo-R2 using Stata. Additionally, the marginal effects were computed for model interpretation as they indicate the magnitude of effect resulting from a one-unit change in an independent variable on outcome category probability.

Traditional ordered logistic regression is limited as the threshold values are assumed to be fixed and error variances are assumed to be homoscedastic. A potential extension to ordered logit models to account for unobserved heterogeneity includes the ordered mixed logit model which allows for random coefficients across explanatory variables and the heteroscedastic models allow the error term's variance to vary (Torres-Reyna, 2007). Although the inclusion of random parameters was not significant in the models of each

individual period, random parameters were included in a final pooled model which introduced dummy variables for the “During COVID-19” and “After COVID-19”, using the “Prior to COVID-19” level of comfort as the base case.

4. Results and discussion

4.1. Comfort shared mode use before COVID-19

Ordinal logistic regression models for the level of comfort in shared mobility before the pandemic, as presented in Table 12, indicate a general comfort with shared mobility before COVID-19. The estimate coefficient’s significance and value can be interpreted that for each one-unit increase, the dependent variable is expected to change by the estimated coefficient in the ordered log-odds scale. The average marginal effects, reported in Table 13, can be interpreted as the average changes in probability given a one-unit change in the explanatory variable. The extrovert attitudinal factor, active user and the occasional user indicator are significant and positive across all models. The significance of these positive coefficients means that for each mode, if a person previously used the mode “1–3 times a month” or “less than once a month”, or if a person displayed outgoing and extrovert attitudes, they will be more comfortable using the mode. These results support the hypothesis that interest in shared mobility can be associated with the expression of extraversion, openness, and agreeableness personality traits (Axsen, 2019). The impact of prior experience on comfort supports the school of thought that undertaking unfamiliar travel has the potential to make services easier and more comfortable for them to use by reducing the psychological barriers of uncertainty (Schmitt et al., 2019). In addition to usage of the mode being modeled, a multimodal indicator factor is significant across shared ride-hailing and transit in predicting comfort. The multimodal indicator is a binomial variable; if an individual used a ride-hail, shared ride-hail, transit, bicycle, shared bicycle, or shared e-scooter at least once a week before the pandemic, they were considered multimodal. This variable is modified for each mode to avoid multicollinearity issues in the model; for example, the transit multimodal variable is 1 if the individual uses ride-hail, shared ride-hail, bicycle, shared bicycle, or shared e-scooter at least once a week in the pre-pandemic period. The significance of the multimodal variable is reflective of the interconnected relationship between multimodality and shared mobility (Circella, 2018). In the private ride-hailing model before the pandemic, active and occasional private ride-hailing users, as well as multimodally inclined respondents, were found to have a higher probability of strongly agreeing that they would feel comfortable using private ride-hailing; The average marginal effect equal to 0.353 and 0.368 in the strongly agree category suggests that active and occasional users had a higher probability to strongly agree that they felt comfortable using private ride-hailing before the pandemic. Males and respondents with a household income lower than \$50 K were found to be negative and significant in the private ride-hailing before the pandemic model. On average, males had a 0.066 lower probability to strongly agree, and lower income respondents had a 0.102 lower probability to strongly agree that they were comfortable using private ride-hailing. The “Follow Safety Measures” and ‘Extrovert’ attitude factors were positive and significant in the private ride-hailing model. This indicates that that people who adhere to suggested rules and are comfortable around others tend to be more comfortable than others with the sharing experience.

The trend of prior usage with the mode impacting comfort continued in the shared ride-hailing model as the average marginal effect on strongly agree for an active user was 0.204, which suggest at prior usage results in a higher probability to strongly agree that they

Table 12
Ordinal Logit Model of Comfort Before the COVID-19 for Private Ride-Hailing, Shared Ride-Hailing, and Transit.

Ordinal Logistic Model of Comfort Before the COVID-19 Pandemic						
Variable	Private Ride-Hailing		Shared Ride-Hailing		Public Transit	
	Coefficient	Sig.	Coefficient	Sig.	Coefficient	Sig.
<i>Attitude Factors</i>						
Follow Safety Measures	0.307	***			0.372	***
Extrovert	0.241	**	0.493	***	0.175	*
Trust Precautions			0.279	***		
<i>Socio-Demographics</i>						
Male Indicator	-0.334	*				
Age Indicator (Boomer)			-0.495	**		
Lower Income Indicator	-0.513	**				
Higher Income Indicator			-0.466	***		
<i>Prior Usage Indicators</i>						
Occasional User	1.776	***	0.747	***	1.391	***
Active User	1.865	***	1.152	***	1.593	***
Multimodal User	0.388	*	0.279	*	0.489	**
<i>Thresholds</i>						
μ_1	-2.806		-2.437		-2.200	
μ_2	-1.965		-0.785		-0.913	
μ_3	-0.915		-0.046		-0.080	
μ_4	1.018		1.424		1.644	
# of Responses	787		787		787	
McFadden R-Squared	0.0972		0.0627		0.0870	

*P < 0.05, **P < 0.01, ***P < 0.001.

Table 13

Average Marginal Effects of the Ordinal Logit Model Estimation of Comfort Before the COVID-19 for Private Ride-hailing, Shared Ride-hailing, and Transit.

Marginal Effects: Private Ride-Hailing Before the COVID-19 Pandemic					
	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neither Agree nor Disagree</i>	<i>Agree</i>	<i>Strongly Agree</i>
Follow Safety Factor	−0.006	−0.006	−0.013	−0.036	0.061
Extrovert Factor	−0.005	−0.005	−0.010	−0.028	0.048
Male Indicator	0.007	0.007	0.014	0.039	−0.066
Lower Income Indicator	0.010	0.010	0.022	0.060	−0.102
Occasional User Indicator	−0.036	−0.035	−0.076	−0.206	0.353
Active User Indicator	−0.037	−0.037	−0.079	−0.215	0.368
Multimodal Indicator	−0.008	−0.008	−0.017	−0.045	0.077
Marginal Effects: Shared Ride-Hailing Before the COVID-19 Pandemic					
	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neither Agree nor Disagree</i>	<i>Agree</i>	<i>Strongly Agree</i>
Extrovert Factor	−0.033	−0.054	−0.017	0.017	0.087
Trust Precautions Factor	−0.189	−0.030	−0.010	0.010	0.049
Age Indicator (Boomer)	0.032	0.051	0.016	−0.016	−0.083
High Income Indicator	0.029	0.047	0.015	−0.015	−0.076
Occasional User Indicator	−0.019	−0.030	−0.010	0.010	0.050
Active User Indicator	−0.078	−0.125	−0.040	0.039	0.204
Multimodal Indicator	−0.050	−0.081	−0.026	0.025	0.132
Marginal Effects: Transit Before the COVID-19 Pandemic					
	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neither Agree nor Disagree</i>	<i>Agree</i>	<i>Strongly Agree</i>
Follow Safety Factor	−0.012	−0.020	−0.019	−0.027	0.078
Extrovert Factor	−0.006	−0.009	−0.009	−0.013	0.037
Occasional User Indicator	−0.046	−0.075	−0.071	−0.099	0.291
Active User Indicator	−0.053	−0.086	−0.081	−0.114	0.334
Multimodal Indicator	−0.016	−0.026	−0.025	−0.035	0.103

felt feel comfortable using shared ride-hailing. Unlike the transit and private ride-hailing models which found a similar influence levels from active and occasional users, occasional users in the shared ride-hailing model had only a 0.005 higher probability of strongly agreeing that they felt comfortable using shared ride-hailing before the pandemic. This finding indicates that attitudes towards shared ride-hailing are complex and should be examined further. Age and income indicator variables were negative and significant in the shared ride-hailing model. Respondents from the “Boomer” generation (56–74 yrs. old) and respondents with a household income more than \$100 K were found to be less comfortable using shared ride-hailing services. This finding is consistent with previous studies (Alonso-González et al., 2021).

Unlike the private ride-hailing and shared ride-hailing models, no socio-demographic variables were found to be significant in the transit model. Prior usage variables were significant in predicting the level of comfort using transit; active transit users had on average a 0.334 higher probability to strongly agree, occasional transit users had on average a 0.291 higher probability to strongly agree, and multimodal transportation users 0.103 higher probability to strongly agree that they felt comfortable using transit before the pandemic.

4.2. Comfort of shared mode use during COVID-19

Ordinal logistic regression models for the level of comfort using shared mobility during the pandemic assuming the October 2020 Atlanta metro area COVID-19 risk, as presented in Table 14, indicated that the factored attitudes related to “Follow Safety Measures” factor negatively influenced level of comfort across all modes and “Trust Precautions” positively influenced level of comfort across all modes. As the factor related to the importance of wearing masks and air circulation increased for individuals, the level of comfort using all shared modes decreased. As the factor that measures trust in the sanitization measures of shared mobility increased for individuals, the level of comfort using all shared modes increased. The variable related to awareness of virus spread, “Germophobe” attitude factor, was negative and significant in the private ride-hailing and transit models. As the spread of the virus becomes more important for individuals, their level of comfort using private ride-hailing and transit decreases. This variable was not found to be significant in the shared ride-hailing model. This difference between modes may be due to the suspension of shared ride-hailing services and resulting lack of understanding of comfort levels using this mode. Unlike the level of comfort before the pandemic models, the extrovert factor was not included in this model as it was not statistically significant. This indicates that during the pandemic, even being an extrovert did not influence level of comfort using shared mobility.

Prior usage did impact level of comfort across all modes during the pandemic. A dummy variable for respondents who had never used the mode (non-users) was significant and negative in all shared modes during the pandemic. A transit non-user had, on average, a 0.172 higher probability to strongly disagree that they felt comfortable using transit during the pandemic. A private ride-hailing non-user had, on average, a 0.129 higher probability to strongly disagree that they felt comfortable using private ride-hailing during the pandemic. The smallest non-user impact on comfort during the pandemic was estimated in shared ride-hailing; non-users had, on average, only a 0.078 higher probability to strongly disagree that they would feel comfortable using that mode during the pandemic, as seen in Table 15.

Table 14
Ordinal Logit Model of Comfort During the Pandemic (October 2020) for Private Ride-hailing, Shared Ride-hailing, and Transit.

Ordinal Logistic Model of Level of Comfort During the COVID-19 Pandemic						
Variable	Private Ride-Hailing		Shared Ride-Hailing		Public Transit	
	Coefficient	Sig.	Coefficient	Sig.	Coefficient	Sig.
<i>Attitude Factors</i>						
Follow Safety Measures	-0.390	***	-0.691	***	-0.219	**
Trust Precautions	0.993	***	1.059	***	0.688	***
Germaphobe	-0.155	*			-0.266	***
<i>Prior Usage Indicator</i>						
Non-User	-0.949	***	-0.424	**	-0.867	***
<i>Thresholds</i>						
μ ₁	-1.833		-0.175		-0.930	
μ ₂	-0.328		1.581		0.509	
μ ₃	0.381		2.513		1.271	
μ ₄	1.927		3.770		2.825	
# of Responses	787		787		787	
McFadden R-Squared	0.0937		0.1422		0.0630	

*P < 0.05, **P < 0.01, ***P < 0.001.

4.3. Comfort of shared modes Post-COVID-19

Ordinal logistic regression models for the level of comfort in shared mobility in the future when a vaccine is available are presented in Table 16. Similar to the before COVID models, the future models included attitudes related extroversion that increased level of comfort across all modes. As the factor related to the agreement of trusting shared mobility precautions and sanitization increased, the level of comfort using all shared modes in the future increased. The variables related to awareness of virus spread, germophobe attitude factor, was negative and significant in the transit model. Germ-conscious individuals are less comfortable using transit in the future than other users. The factor related to following safety measures was only significant and positive in the transit model after the pandemic.

Sociodemographic characteristics in the models reveals the non-white variable negatively impacts the level of comfort of all shared modes in the future. As seen in Table 17, a respondent that is non-white had on average a 0.138, 0.161, 0.118 lower probability of strongly agreeing that would feel comfortable using ride-hailing, shared ride-hailing, and transit respectively after the pandemic. Income variables were significant in the level of comfort of private ride-hailing and shared ride-hailing models. The marginal effects indicated that respondents with a household income of \$50 K or less had a 0.097 lower probability of strongly agreeing that they would feel comfortable using private ride-hailing in the future and respondents with a household income of \$10 K or more had a 0.051 lower probability of strongly agreeing that they will feel comfortable using shared ride-hailing in the future. The male variable is positive and significant for future levels of comfort in shared ride-hailing and transit models. The inclusion of this variable in the future model may be explained as other studies have found being male was uniformly associated with lower risk perceptions (Dryhurst et al., 2020). Indicator variables for generation groups of “Boomer” and “Gen Z” are negative and significant in the shared ride-hailing and transit models respectively. Similar to the pre-COVID mode, respondents in the “Boomer” generation (56–74 years old) were less likely to agree that they would feel comfortable using shared ride-hailing in the future. Gen Z respondents (aged 18–24) were less likely to strongly agree that they would feel comfortable using transit in the future when a vaccine is available.

Table 15
Average Marginal Effects of the Ordinal Logit Model Estimation of Comfort During the COVID-19 for Private Ride-hailing, Shared Ride-hailing, and Transit.

Marginal Effects: Private Ride-Hailing During the COVID-19 Pandemic					
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Follow Safety Factor	0.053	0.024	-0.002	-0.031	-0.044
Trust Precautions Factor	-0.135	-0.062	0.006	0.078	0.113
Germaphobe Factor	0.0211	0.009	-0.001	-0.122	-0.018
Non-User Indicator	0.129	0.059	-0.006	-0.075	-0.108
Marginal Effects: Shared Ride-Hailing During the COVID-19 Pandemic					
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Follow Safety Factor	0.127	-0.037	-0.033	-0.033	-0.023
Trust Precautions Factor	-0.194	0.057	0.508	0.508	0.035
Non-User Indicator	0.078	-0.023	-0.020	-0.020	-0.014
Marginal Effects: Transit During the COVID-19 Pandemic					
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Follow Safety Factor	0.043	0.000	-0.010	-0.021	-0.012
Trust Precautions Factor	-0.136	-0.000	0.032	0.066	0.038
Germaphobe Factor	0.053	0.000	-0.013	-0.026	-0.015
Non-User Indicator	0.172	0.000	-0.041	-0.084	-0.048

Table 16
Ordinal Logit Model of Comfort Post-Pandemic in Private Ride-Hailing, Shared Ride-Hailing, and Transit.

Ordinal Logistic Model of Level of Comfort Post-COVID-19						
Variable	Private Ride-Hailing		Shared Ride-Hailing		Public Transit	
	Coefficient	Sig.	Coefficient	Sig.	Coefficient	Sig.
<i>Attitude Factors</i>						
Follow Safety Measures					0.222	**
Extrovert	0.121	*	0.393	***	0.135	*
Trust Precautions	0.507	***	0.563	***	0.384	***
Germaphobe					-0.199	**
<i>Socio-Demographics Indicator</i>						
Male			0.493	***	0.323	*
Age (Boomer)			-0.065	***		
Age (Gen Z)					-0.724	**
Racial (Non-White)	-0.718	***	-0.615	***	-0.759	***
Lower Income	-0.505	**				
Higher Income			-0.513	***		
<i>Prior Usage Indicators</i>						
Occasional User	1.259	***	0.431	**	1.093	***
Active User	1.643	***	0.663	*	1.014	***
Multimodal User			0.305	*	0.314	*
<i>Thresholds</i>						
μ_1	-2.862		-2.255		-2.166	
μ_2	-1.750		-1.859		-0.626	
μ_3	-0.314		-0.088		0.590	
μ_4	1.702		2.371		2.400	
# of Responses	787		787		787	
McFadden R-Squared	0.0728		0.0795		0.0855	

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Table 17
Average Marginal Effects of the Ordinal Logit Model Estimation of Comfort Post-COVID for Private Ride-hailing, Shared Ride-Hailing, and Transit.

Marginal Effects: Private Ride-Hailing Post COVID-19					
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Extrovert Factor	-0.004	-0.005	-0.011	-0.003	0.023
Trust Precautions Factor	-0.017	-0.023	-0.047	-0.011	0.097
Lower Income Indicator	0.017	0.023	0.047	0.011	-0.097
Race Indicator (Non-White)	0.024	0.032	0.067	0.015	-0.138
Occasional User Indicator	-0.042	-0.057	-0.117	-0.027	0.242
Active User Indicator	-0.054	-0.074	-0.152	-0.035	0.316
Marginal Effects: Shared Ride-Hailing Post COVID-19					
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Extrovert Factor	-0.037	-0.042	0.005	0.052	0.053
Trust Precautions Indicator	-0.052	-0.060	0.001	0.055	0.056
Male Indicator	-0.046	-0.052	0.001	0.048	0.049
Higher Income Indicator	0.048	0.054	-0.001	-0.050	-0.051
Race Indicator (Non-White)	0.057	0.065	-0.002	-0.060	-0.061
Age Indicator (Boomer)	0.060	0.068	-0.002	-0.063	-0.064
Occasional User Indicator	-0.040	-0.046	-0.017	0.005	0.069
Active User Indicator	-0.068	-0.070	0.002	0.065	0.065
Multimodal Indicator	-0.02	-0.032	0.001	0.030	0.030
Marginal Effects: Transit Post COVID-19					
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Safety Measures Factor	-0.012	-0.0188	-0.014	0.010	0.035
Extrovert Factor	-0.007	-0.011	-0.008	0.006	0.021
Trust Precautions	-0.021	-0.033	-0.024	0.017	0.060
Germaphobe Factor	0.011	0.017	0.012	-0.009	-0.031
Male Indicator	-0.018	-0.027	-0.020	0.015	0.050
Race Indicator (Non-White)	0.041	0.064	0.047	-0.034	-0.118
Age Indicator (Gen Z)	0.040	0.061	0.045	-0.032	-0.113
Occasional User Indicator	-0.060	-0.093	-0.067	0.049	0.170
Active User Indicator	-0.055	-0.0859	-0.062	0.046	0.158
Multimodal Indicator	-0.017	-0.027	-0.019	0.014	0.049

4.4. Comfort of shared modes throughout COVID-19

To further investigate the change in level over time, a single pooled model was evaluated with comfort dummy variables introduced for the “During COVID-19” and “After COVID-19”, using the “Prior to COVID-19” level of comfort as the base case. A random parameters ordinal logistic regression model for each shared mode was estimated to display the incremental effects related to the COVID-19 pandemic. Random parameters were normally distributed, and the standard deviation of parameter distribution is displayed in parenthesis in Table 18. Examining the model, the perceived level of comfort decreased across all shared modes during and after COVID-19 when compared with comfort levels prior to the pandemic, as seen in negative and significant indicator variable coefficients in Table 18. The corresponding marginal effects are in Table 19. The coefficients related to the period during the pandemic were around three times larger than the coefficient related to the future period after the pandemic. Comparing across modes, transit had the largest negative coefficients of level of comfort during and after the pandemic, followed by shared ride-hailing comfort. This suggests that as more individuals are involved in the sharing process, respondents may report a lower level of comfort.

Examining the attitudinal factors, respondents who trusted precautions and display extrovert characteristics perceived a higher level of comfort using shared modes, as indicated by the positive and significant coefficients. Coefficients related to prior modal preference suggested that active and occasional users will be significantly more comfortable using shared modes during the pandemic. These respondents had prior experience so were able to base their attitudes on personal experience instead of hypothetical experience.

The private ride-hailing model also include a single negative socio-demographic variable for lower income respondents. This means that respondents who made \$50 K or less were less likely to strongly agree that would feel comfortable using private ride-hailing. As private ride-hailing services can be a more expensive shared mobility option, private ride-hailing is typically more accepted by higher-income individuals (Alemi et al., 2019). This hypothesis is further confirmed as a higher-income indicator coefficient was negative and significant in the share ride-hailing model. Age and gender were also significant in the shared ride-hailing model with more males agreeing that they would feel comfortable using shared ride-hail and less of the older generation agreeing that they would feel comfortable using shared ride-hailing.

Table 18

Pooled Ordinal Logistic Regression Model of Level of Comfort During the Pandemic with the Current COVID-19 Risk for Private Ride-Hailing, Shared Ride-Hailing, and Transit.

Pooled Ordinal Logistic Model of Level of Comfort for Private Ride-Hailing, Shared Ride-hailing, and Transit						
Variable	Private Ride-Hailing		Shared Ride-Hailing		Public Transit	
	Coefficient	Sig.	Coefficient	Sig.	Coefficient	Sig.
<i>Time Indicator</i>						
During COVID-19	-3.144	***	-3.516	***	-3.769	***
After COVID-19	-1.388	***	-0.979	***	-1.370	***
<i>Attitude Factors</i>						
Extrovert	0.191 (0.053)	**	0.503 (0.511)	***	0.177 (0.322)	**
Trust Precautions	0.576 (0.741)	***	0.673 (0.316)	***	0.343 (1.004)	***
Germaphobe					-0.268 (0.275)	***
<i>Socio-Demographics Indicator</i>						
Lower Income	-0.362	**				
Higher Income			-0.521 (0.656)	***		
Male			0.268 (0.592)	*		
Age (Boomer)			-0.660 (1.632)	***		
Age (Gen Z)					-0.673 (1.133)	*
Non-White					-0.330 (0.577)	*
<i>Prior Usage Indicators</i>						
Active User	1.748 (1.411)	***	0.829	***	1.380	***
Occasional User	1.438 (0.517)	***	0.423	**	1.150	***
<i>Thresholds</i>						
μ ₁	-3.724		-3.538		-3.815	
μ ₂	-2.404		-1.481		-2.097	
μ ₃	-1.402		-0.324		-0.975	
μ ₄	0.589		1.488		1.058	
Log-Likelihood (Full)	-2886.83		-3085.93		-3049.31	
# of Responses	2,361		2,361		2,361	

*P < 0.05, **P < 0.01, ***P < 0.001.

Table 19

Pooled Ordinal Logistic Regression model of Level of Comfort During the Pandemic with the Current COVID-19 Risk for Private Ride-Hailing, Shared Ride-Hailing, and Transit.

Marginal Effects: Private Ride-Hailing					
	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neither Agree nor Disagree</i>	<i>Agree</i>	<i>Strongly Agree</i>
During COVID-19 Indicator	0.247	0.172	0.090	-0.073	-0.436
Future Indicator	0.100	0.052	0.034	0.014	-0.201
Extrovert Factor	-0.012	-0.009	-0.006	-0.001	0.028
Trust Precautions Factor	-0.036	-0.028	-0.018	-0.003	0.086
Lower Income Indicator	0.024	0.0178	0.011	0.005	-0.053
Active User Indicator	-0.064	-0.071	-0.061	-0.0700	0.265
Occasional User Indicator	-0.092	-0.072	-0.043	-0.003	0.210
Marginal Effects: Shared Ride-Hailing					
	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neither Agree nor Disagree</i>	<i>Agree</i>	<i>Strongly Agree</i>
During COVID-19 Indicator	0.365	0.122	-0.016	-0.173	-0.297
After COVID-19 Indicator	0.102	0.034	-0.004	-0.048	-0.082
Extrovert Factor	-0.051	-0.015	0.003	0.021	0.042
Trust Precautions Factor	-0.069	-0.021	0.004	0.030	0.056
Higher Income Indicator	0.062	0.011	-0.009	-0.030	-0.034
Male Indicator	-0.021	-0.014	-0.003	0.007	0.031
Age Indicator (Boomer)	0.074	0.014	-0.008	-0.034	-0.047
Active User Indicator	-0.086	-0.029	0.004	0.041	0.070
Occasional User Indicator	-0.044	-0.015	0.002	0.021	0.036
Marginal Effects: Transit					
	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neither Agree nor Disagree</i>	<i>Agree</i>	<i>Strongly Agree</i>
During COVID-19 Indicator	0.302	0.160	0.054	-0.074	-0.441
After COVID-19 Indicator	0.110	0.058	0.019	-0.027	-0.160
Extrovert Factor	-0.139	-0.007	-0.002	0.003	0.020
Trust Precautions Factor	-0.028	-0.012	-0.004	0.007	0.036
Germaphobe Factor	0.021	0.011	0.003	-0.005	-0.031
Non-White Indicator	0.031	0.012	0.002	-0.012	0.034
Age Indicator (Gen Z)	0.056	0.027	0.008	-0.015	-0.077
Active User Indicator	-0.111	-0.058	-0.020	0.027	0.162
Occasional User Indicator	-0.092	-0.049	-0.016	0.023	0.135

5. Conclusions and further research

This study provides important insight into the comfort and usage of shared modes before the pandemic, during a re-opening phase of the pandemic, and the predicted future when a vaccine is available. Data collected from the Atlanta area in October does not represent the general population, but trends seen in regression models and data analysis are important when predicting the long-term impact of COVID-19 on our willingness to use shared mobility. Due to social distancing and stay-at-home orders during the pandemic, the actual usage of shared mobility transportation modes, including private ride-hailing, shared ride-hailing, and transit, significantly decreased when compared to usage before the pandemic. Potential virus exposure from other riders contributed to a lower level of comfort for shared modes throughout the pandemic despite the reopening of the economy. In response to this discomfort, shared modes implemented many precautionary measures including suspending shared ride-hailing, requiring all passengers and drivers to wear masks, and encouraging social distancing and air circulation. These measures were generally viewed as positive and a portion of the population that trusted these precautions did not indicate a decrease in comfort during the pandemic for shared modes. In the future, comfort levels associated with using shared mobility are expected to increase but not completely return to previous levels. The change in levels of comfort post-pandemic varies among socio-demographic variables like race, income, and age. As a vaccine becomes reality and the world returns to a “new normal” this research provides essential insights for planners and policymakers to better prepare for the post-pandemic era. To build on this work, further research should collect and analyze the changes to comfort and actual usage for trip purposes. As more survey data becomes available, this analysis should be extended across cities and compared to develop local and national trends.

CRedit authorship contribution statement

Rebecca Kiriazes: Conceptualization, Methodology, Data curation, Investigation, Writing – original draft, Writing – review & editing. **Kari Edison Watkins:** Conceptualization, Methodology, Writing – review & editing, Writing – original draft, Supervision.

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: Rebecca Kiriazes, Kari Watkins.; data collection, analysis and interpretation of results, draft manuscript preparation: Rebecca Kiriazes, Kari Watkins

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