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Summary
Dramatic reductions in carbon emissions must take place immediately. A human-centric method of reducing environmental impacts is to "nudge" people away from single-occupancy vehicles (SOVs) toward more sustainable commuting options. While an abundance of research has focused on external determinants of mode choice, we know much less about the behavioral determinants. The field of behavioral science is overdue for a focus on transportation. This paper is meant to facilitate communication between researchers, practitioners, and policymakers in part by developing a behaviorally-informed framework that can be leveraged by policymakers, government, and organizations worldwide. We also describe the founding of our multidisciplinary team and outline lessons learned.

Keywords: Behavioral science; transportation demand management; mode shift; behavior change' commuting; single-occupancy vehicle commutes; climate change

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To reflect the collaborative nature of this action-oriented research, the authors are listed in reverse alphabetical order.

Driving as a Consumer Cause of Climate Change

Dramatic reductions in emissions must take place this decade to avoid expensive and catastrophic climatic events. If emissions continue at their current pace, researchers expect a 7°F increase in global temperatures by 2100. This would cost the US about $400 billion each year or 1.25x more than heart disease, the leading cause of death.[1] This rise in temperatures is projected to cause calamitous human suffering and ecological collapse. More than a million plant and animal species are at risk of extinction[2] and the world could endure "untold human suffering" resulting from hurricanes, wildfires, and floods.[3] People are already suffering: The consequences of COVID-19 are exaggerated by causes of global warming like pollution. In areas with high levels of air pollution, people are more likely to die when exposed to the virus.[4]

Recent estimates suggest that commuting behavior can have significant environmental impacts.[5] In the US, motor vehicles accounted for 75% of carbon monoxide pollution, as well as one-third of the air pollution that produces smog.[6] Transportation decisions like driving and air-travel are thought to contribute 27% of greenhouse gas emissions in the US each year.[7]

In a typical workweek, about 128 million people in the US—86% of workers—drive to work by car and over three-quarters drive-alone. Drive-alone trips are classified as single-occupancy vehicle (SOV) commutes.[8,9] To slow the decline of rising global temperatures over the next two decades, widespread changes in transportation behaviors are needed. With 15% of carbon emissions in the US and 24% globally resulting from car emissions,[10] it is difficult to imagine a successful climate mitigation strategy that does not include commuting behaviors.

Driving also incurs significant cost for municipalities and individuals. Each of the 4.18 million miles of road in the US costs governments about $24,000 per year to preserve.[11] For the typical American, the average vehicle costs about $9,500 per year to own and operate.[12]

Given these benefits, how can transportation managers and policymakers encourage individuals to adopt more sustainable modes of transportation?

The Beginnings of a Behavioral Approach to Transportation

To date, researchers and policymakers have developed a variety of measures to increase consumer demand for sustainable transportation and decrease demand for drive-alone trips. These "Transportation Demand Management" (TDM) methods are defined as "strategies and programs designed to encourage more efficient use of transportation resources."[13] Academics and practitioners design TDM programs to counteract the incentives, norms, and local infrastructure that encourage drive-alone trips by increasing individual awareness and incentivizing sustainable transportation.[14]

Over the past 30 years, researchers and policymakers have tested various measures to promote sustainable transportation. These measures generally fall into two categories: structural and psychological.[15] Structural or "hard" interventions focus on changing economic incentives or modifying the physical environment, such as closing roads to build bicycle lanes. Psychological or "soft" interventions focus on changing attitudes, beliefs, values, and norms.

Most research has focused on the role of structural interventions for shaping transportation behavior by exploring how land use[16], public transit and parking infrastructure[17,18,19], parking pricing[20], congestion pricing,[21,22] and trip length[23] shape commuting behavior. See[24] for a review. A growing—yet nascent—branch of transportation research has started to explore the effect of psychological levers for shifting transportation behavior.

Most research exploring the efficacy of 'softer' interventions has relied on self-reported survey data, focus groups, and correlational data as opposed to experimental evidence.[25, 26, 27] In a meta-analysis published in 2020 that explored the consequences of psychologically-informed interventions on driving behavior, [28] only two studies evaluated intervention effectiveness using objective measures. One study used GPS data, the other used self-reported distance on a map. In this same meta-analysis, the authors identified 2,920 published papers on mode shift. Only 30 of these studies were classified as randomized control trials (RCTs). For additional meta-analytic evidence supporting this point see the following citations.[29,30]

The Initial Need For & Development of our Team

To capitalize on growing interest from the TDM community to better understand the efficacy of psychologically-informed interventions,[31] and to overcome the limitations of correlational and self-reported studies,[32] we assembled a multidisciplinary team to test whether behaviorally-informed interventions that have shown to be successful in other domains might also encourage sustainable transportation. The creation of this team—which includes academics, applied researchers, and TDM professionals—fits with an emerging focus toward understanding the effectiveness of psychologically-informed interventions for changing behavior at scale.[33]

Due to far-reaching success in other domains, behaviorally-informed interventions have gained interest from TDM practitioners to reduce SOV commutes[34,35] However, given the quality issues of data collected on commuter mode shift, the efficacy of applying a behavioral approach to transportation is largely unknown.[36] Most research on mode shift has been published by transportation researchers.[37] Behavioral science has largely overlooked transportation behavior outside of consumer decisions about whether or not to purchase fuel efficient vehicles.[38] While behavioral aspects of fuel-efficient car selection have been studied,[39] there is much less research examining the behavioral aspects of the decision to drive (i.e., car use). See [40] for similar arguments. We propose that more research should apply behavioral insights by considering the behavioral barriers that we describe in this paper.

Collaboration Process and Initial Projects

To bridge the related fields of TDM and behavioral science, we established a multi-disciplinary team of applied researchers, academics, and industry partners by working with Alta Planning + Design, a consulting firm that frequently collaborates with TDM practitioners and academics. In collaboration with Alta, we distributed an invitation to public agencies and private companies in the US. In this call, we asked interested parties to submit a brief statement of interest in serving as a partner for research related to transportation mode shift away from driving alone, with a

focus on carpooling while being open to other mode shifts.[1] This call to action yielded 32 interested partners. Of these potential partners, we started working with more than 10 cities, transportation initiatives, technology platforms, and other organizations. Our recruitment materials are available through the Open Science Framework: https://osf.io/ufcht/.

As behavioral scientists working with cost-sensitive companies, organizations, and government agencies, we focused our research on "soft interventions" that did not involve monetary rewards. This is not to say that hard incentives are ineffective. While outside the scope of this paper, case studies from jurisdictions across the US show that financial and non-financial rewards can effectively motivate behavior change. See Table 1 for representative examples.

Although many people say they wish to commute less by car, it is difficult for individuals to follow through on their intentions, especially when trying to change habitual commuting behavior[41,42]. Thus, before meeting with potential partners, we considered the behavioral barriers that may be especially likely to prevent individuals from changing their transportation (driving) behaviors. In conducting this literature review, we identified several possible barriers.

Behavioral Barriers to Deciding to Change Commuting Behaviors

Based on the literature, we observed several factors that would likely influence whether people considered reducing their SOV commutes: availability bias, commute impedance, loss aversion, opportunity cost neglect, present bias, status quo bias, and sunk cost bias.

Availability Bias: People tend to think that examples that easily come to mind are more representative than is the case.[43] Because the popular media glorifies driving, the most easily accessible image of driving is one of prestige and freedom.[44] In contrast, alternative forms of transportation like taking the bus are frequently portrayed as difficult, dirty, associated with lower socioeconomic status, or physically unsafe.[45] As a result of availability bias, people could be less likely to want to take transit or bike.[46]

Commute Impedance: People often suffer psychological distress when their goal-directed behavior is constrained. As related to experiencing challenges while commuting, such as traffic, this is known as the commute impedance model.[47] According to this model, alternative modes might be less desirable because they are more uncertain and variable.[48] Thus, reducing the variability or lack of control over alternatives could increase the attractiveness of these options.

Loss Aversion: People dislike losses more than they like equivalent gains. Thus, people are more likely to exhibit risk aversion and continue with their current behavior unless they are motivated by the threat of a loss.[49] When deciding which mode of transportation to use, the downsides of alternative modes could loom large in an individuals' mind. For example, the freedom to relax on the bus might not figure as prominently in decision-making as the

[1] Given our partnership with technology platforms that could provide us with behavioral outcome data, we focused our call to action on carpooling.

anticipated stress of waiting for an unpredictable bus or the lost independence. The perceived benefits of the alternative mode must outweigh the perceived cost of switching modes.

Opportunity Cost Neglect: People fail to consider the opportunity costs—the sacrifices they are making by selecting one choice over another—when making decisions.[50,51,52] Related to driving, each trip has variable costs like fuel and parking that often go unnoticed. These invisible variable costs hide the true opportunity cost of driving to work and prevent behavior change.

Present Bias: Present bias is the tendency to minimize the value of future events and outcomes and prioritize the present.[53] Driving is more convenient and familiar than other modes, and the health and environmental benefits of sustainable commutes can take years to observe. Therefore, present bias can shape how consumers perceive sustainable transportation.[54]

Status Quo Bias: Status quo bias is the reluctance to move away from an established point of reference. This can lead people not to change their behavior unless they have a strong motivation to do so.[55] Most people drive to work. Because commuting is a deeply ingrained habit, people often put little thought into their mode choice. As commuting changes involve altering a *habitual* behavior, people are more likely to consider the losses related to the behavior change—such as how much slower the commute is compared to driving.[56]

Sunk Cost Bias: Relatedly, people feel more committed to actions that they have already invested time, money, and effort into. [57] Most car owners have already made an upfront investment to purchase their vehicle or have already paid for an annual parking permit, thus encouraging commuters to drive—even if they could plausibly commute via other modes.[58]

Together, these behavioral barriers suggest that to encourage people to shift their commuting behaviors away from driving, behaviorally informed interventions need to highlight the easily hidden costs of driving, the often-hidden benefits of alternative modes, and ensure that the decision to switch from driving to alternative modes is easy and attractive.

Behavioral Barriers to Deciding to Execute Commuting Behavior Change

We also observed several factors that could influence whether people *follow through* on intentions to shift their transportation behavior: friction costs, default bias, overconfidence, and social norms. These behavioral barriers are especially important to consider because people often state that they are interested in taking the bus, walking, or biking to work; however, very few people follow through with the decision to change their behavior.[59]

Default Bias: 'Default bias' is the idea that a default option will dominate any situation where it is implemented. An important transportation default is free or subsidized parking, which will make driving feel like the easier and cheaper option. In this context, employees are more likely to drive because it is easier: There are no concerns about finding a spot and driving feels free.

Friction Costs: People select the easiest option to avoid making difficult decisions and expending effort.[60] As a result of the unclear benefits, it can be difficult for people to engage in sustainable transportation as this behavior often has 'friction' such as weather or uncertainty.[61]

Overconfidence Effect: People believe in their ability more than they should in light of their prior performance.[62] People also think that they will have more time to change their behavior than they do and they underestimate the amount of effort needed to follow through.[63] This effect prevents individuals from commuting in sustainable ways. Firstly, if individuals say they are going to commute via biking, but do not think through the barriers that could prevent this action, like rain, they are unlikely to follow through.[64] Second, even if individuals do commit to changing their behavior, they might delay the decision indefinitely.[65]

Social Norms: People's actions are influenced by their beliefs about what other people do (descriptive norms) and their beliefs about what others think they should do (injunctive norms). Most people believe that other people get to work by driving alone, and this is driven by a true descriptive norm in most of the United States.[66] Many places are missing pro-environmental norms that could lead to more sustainable behavior.[67] And, stigma exists around alternative transportation modes like taking the bus—which is seen as lower in social status than driving.[68]

These behavioral barriers suggest that in order to encourage people to follow through with their intentions to change their behavior, it is important to cultivate positive norms around sustainable transportation by making this behavior more visible (and driving less visible) and by helping people identify how to overcome possible barriers such as rain and service outages.

Structural and Practical Barriers

In addition to behavioral barriers, we considered structural and practical barriers that deter the widespread use of alternative modes of transportation. For example, we considered lack of knowledge about the existence of alternative routes and services including the fastest or safest route or lack of knowledge about the financial and health-relevant benefits of transportation. [69] An often-cited barrier against the use of alternative transportation modes is the lack of quality infrastructure. Thus, we also considered the availability and quality of available infrastructure.[70] Based on our literature review, we decided that any companies or organizations that wanted to work with our team had to explicitly address at least one of the barriers we had identified.

Our Partnership Process:

Step 1: Partner with Motivated and Aligned Organizations

From the 32 organizations who reached out, we partnered with 10 groups. We prioritized organizations which demonstrated strong leadership, data-oriented decision-making, and openness to new ideas. Partners had to provide behavioral outcome data and have the capacity to conduct RCTs. Based on statistical best practices, we targeted organizations with at least 500 potential respondents.[71] To ensure partner organizations had these qualities, we verbally implemented an application form during initial phone calls. See https://osf.io/ufcht/.

Step 2: Identify and Define the Unique Challenge the Organization is Facing
After an initial conversation and verbal agreement of a formal partnership, we signed data sharing agreements and started to work in a collaborative manner to co-design behaviorally-informed interventions. Our group reviewed existing materials, conducted kick-off meetings with key stakeholders, and agreed to a project plan and timeline.

Each partner organization faced different challenges. At one organization, new employees did not receive clear information about alternative transportation modes. At another organization, parking was free, transit passes cost hundreds of dollars each month, and the organization did not highlight the often-hidden costs of driving. Given that each organization faced different behavioral barriers, it was important to identify which behavioral barrier identified in our literature review was most relevant to each partner organization.

Step 3: Explore the Context of These Organizational Challenges
We discussed levers to help users overcome barriers toward sustainable transportation. At each organization, we attempted to observe users in their natural context by conducting qualitative interviews or surveys, and/or analyzing secondary data. Building on Steps 1-3, we built a behavioral map that outlined the theory of change that might best encourage sustainable transportation. This behavioral map considered the conceptual ideas proposed in our literature review as well as the unique challenges that were faced by users within each organization. While seeking to craft "ideal" interventions, we also took feasibility into consideration.[72] A sample behavioral map is available at https://osf.io/ufcht/ and is summarized in Table 2.

Step 4: Prototype and Pilot Initial Intervention
We worked with our partner organizations to develop initial prototypes. In Step 4, we piloted the impact of our solutions to ensure that the interventions would operate as intended when implemented at scale. For example, when working with a university in the South and prototyping a personalized route intervention, we ran a series of one-on-one testing sessions to gain insight into the user experience when interacting with the intervention. In an iterative way, we were able to improve the intervention using insights from the literature and user feedback.

Step 5: Test
We determined whether our solutions worked. Here, we tested the effect of the interventions using RCTs with behavioral outcomes where possible, given that this is considered the "gold standard" experimental approach.[73] To move beyond Step 5, our team is currently continuing to iterate solutions, implement findings, and disseminate our ongoing research.

Our Studies & Initial Results
We will now outline the various experiments that our team has conducted or that are underway as a result of these partnerships. See Table 3 for a comprehensive summary.

Carpooling
In one set of ongoing studies, we are examining behaviorally-informed strategies to encourage sign-ups to and usage of carpool programs. In one study, where the organization provided little

information to new employees about carpooling benefits, we highlighted the existence of these benefits, including social benefits. In another study, we used messages from an organizational leader that highlighted the (often hidden) benefits of the program for financial savings, health, and environmental sustainability—a core organizational priority. In these studies, we formed a joint partnership with ride matching platforms allowing us to track actual carpooling behavior.

Two of these studies are on hiatus given the COVID pandemic – Western Washington University (*N*=3500 employees) and the City of Santa Monica (*N*=2800 employees). In the interim, our team conducted a lab experiment to improve the efficacy of messages we had designed. In this online study (*N*=642), participants were told to imagine that their workplace was starting a carpooling program. They either read about the program (control) or were told that the program could help them get to know their colleagues (social), have quiet time (personal), save money (economic gain) or not lose money from driving (economic loss). Participants in the economic gain condition expressed the greatest interest in signing up for the carpooling program. In contrast, the social message undermined interest. We plan to further test these ideas in the field. See https://osf.io/ufcht/ for study materials and interim results for all studies.

Public Transportation Use

In two additional ongoing studies, we are examining the impact of personalized route plans on bus ridership. In one study, students were also entered into a prize draw each time they rode the bus. As described in Table 3, across both studies, personalized route plans, which make it easier for people to commute in sustainable ways, showed initial success for increasing sustainable commutes and reducing SOV trips, at least on self-reported behavior. Additionally, the effect of personalized route plans was similar to or greater than the lottery incentives. This study suggests that behavioral interventions alone can meaningfully shape commuter behavior, especially when these interventions make alternative transportation modes easy to engage in.

Discussion - Current Thinking on What Works

Over the past two years, our interdisciplinary team has run studies and engaged in countless discussions with organizations, policymakers, TDM practitioners, and behavioral scientists. We have designed and launched ten field experiments with diverse partners including city governments, universities, technology companies, and private corporations ranging in size from 1,000 to 60,000 participants. While interest from the TDM field is extremely high, a reliable funding pipeline does not exist to support this work, slowing progress. More work is needed to understand how to apply and scale behavioral insights to encourage sustainable transportation.

Specifically, it is important to consider the costs and benefits of driving when designing behaviorally-informed interventions. Across our studies, no behavioral intervention resulted in more than a 9% change in transportation behavior—which suggests room for improvement. Additionally, in a recent paper, we found no evidence that behaviorally-informed interventions reduced SOV commutes for 60,000 employees in the United Kingdom who lived near public transportation and who wanted to change their behavior. However, at this workplace, parking was free. [74] In many circumstances, such as when SOV commutes are the easiest and cheapest

option, behavioral interventions alone will not be enough to nudge commuting behaviors. To encourage mode shift, behaviorally-informed interventions will need to be used in combination with 'harder' organizational interventions that encourage sustainable transportation such as financial incentives and pricing fees. Practically, researchers and program designers should look at the entire decision-making context and ensure that existing subsidies, pricing and policies are aligned with the goal of sustainable transportation. In our experience, this is the only situation where a behaviorally-informed intervention has a chance of working.

Building on this insight, we are currently exploring how to restructure parking pricing. In one intervention, we are separating bundled payments. Asking people to pay each time they park could encourage people to evaluate the best option for them on a daily basis and reduce the inertia associated with upfront payment.[75] We are also exploring incremental parking where people will have to pay more to park more, helping to break the driving habit.[76] This research highlights the importance of moving away from studying "hard" and "soft" interventions in isolation, and applying behavioral insights to the design of fines and incentives.

Relatedly, behavioral interventions are only effective when people can realistically engage in an alternative commuting mode, without significant penalties for safety, convenience, and cost. In our own data, interventions were more effective when people lived near the public transportation routes advertised in our communications (Table 3). Introducing high-quality bicycle facilities and dedicated bus lanes, requiring major employers to submit a TDM plan and track progress, and creating and analyzing reduced cost fare programs for low-income residents are a few of the strategies that cities should use to reduce SOV-use. See [77, 78, 79] for recent examples. Organizations and city governments should also consider signing a joint, public commitment to limit the travel engagements of employees, for both safety and sustainability.

Future research should also explore factors that prevent people from switching modes—such as personal benefits. People consistently report disliking commuting. Yet, the "ideal" commute length for most is not zero.[80] In one study, people reported that their average desired commute length was 16 minutes. In another study of over 400 commuters, after variability in commute times due to congestion was considered, people with longer commutes enjoyed them more.[81] This research suggests that commuting by car serves an important psychological function such as providing an opportunity to plan the day and transition between personal and professional responsibilities. A generative area of research is to explore the psychological *benefits* of car commutes in order to better understand how alternative options might generate similar rewards.[82,83] Another generative area is to examine the existence and mitigation of rebound effects where people who drive less fly more given their lower daily carbon footprint, given that similar results have been found in related domains, such as energy consumption.[84]

Finally, more discussion of how to obtain objective data on key outcomes is paramount. Easier collection of smartphone data, bus ridership data, or parking behavior data could expand the scope of behavioral interventions. When objective behavior is measured passively and continuously, studies are less intrusive and easier to run, can assess dynamic changes that unfold over time, and are no longer prone to self-report biases. Lasting partnerships between

researchers, technology platforms and companies are needed to obtain these data, and in doing so, to expand the scope of this work.

Following from our experience of establishing these partnerships, we believe that researchers should develop a proactive research agenda of foundational transportation questions *upfront* and work toward these broad goals over time. We believe that our ongoing interventions could have been more successful if we had outlined a specific set of research questions that we had wanted to try (following the barriers we identified) as opposed to working with interested organizations to test the most convenient research questions. We hope that this article inspires researchers and practitioners to develop their own pipeline of behaviorally-informed projects.

To further advance this work, existing government TDM grant funding sources should start to include high-quality evaluation as an eligible or required funding activity. Existing foundation and government grant programs that are focused on environmental goals should start to acknowledge the importance of behavioral science related approaches in their ongoing work.

Our partnership has highlighted the interest of the TDM community in applying behavioral science principles to mode shift as well as the challenges of conducting research in this area, including the difficulty of accurate measurement. It is our wish that this paper will serve as a springboard for sustained collaborations between researchers and practitioners and provide a framework for understanding how to form and establish these partnerships. We believe that forging partnerships between academics, cities, TDM practitioners, and technology platforms, will best enable the future design and implementation of behaviorally-informed interventions.

Table 1. Updated examples of US-based behavioral studies looking at the effects of incentives on transportation behavior

Incentive	Description/Case Study	Case Study	Results
Financial	Financial incentives can be used to motivate commuting behavior. Financial incentives are often provided to employers in attempts of reducing SOV-use, or shifting employees' behavior from off-peak hours to reduce congestion and simultaneous demand for transportation.		
	BART[85] Methods: Longitudinal Correlational Behavioral Outcome: Reducing Peak Congestion	The San Francisco Bay Area Rapid Transit (BART) implemented a rewards program to encourage riders not to use transit during the most popular window. Participants earned points which they could use to obtain cash or gift cards during the study.	In the first phase of the study, where participants could earn cash, there was a 9.6% reduction in transit trips during the busiest commuter window. In the second phase of the study, where people could earn points to redeem for gift cards by altering travel time, taking surveys, and using BART in the evenings or to the airport, people were willing to alter their typical behavior 6-20%.
	CAPRI Program[86] Behavioral Outcome: Reducing Peak Congestion	The Congestion and Parking Relief Incentives (CAPRI) program provides points and prizes for commuters to avoid peak hours. Commuters either choose to receive cash or random rewards (90% chose random rewards).	People enrolled in this program were 21.2% less likely to commute during morning peak hours and 13.1% less likely to commute during evening peak hours as compared to commuters who were not enrolled in the program. These effects were stronger when participants knew someone who had won a prize: For commuters who had

			friends that recently won a prize, they traveled around 1.5 minutes earlier.
	Chicago Transit Authority[87] Methods: Longitudinal Experimental Behavioral Outcome Reducing Peak Congestion	To Chicago Transit Authority (CAT) wanted to reduce congestion after Chicago Cubs games. To encourage commuters to avoid the Red Line between 5pm-6pm, participants 1) received an alert reminding them of a baseball game 2) a message encouraging them to use the Red Line outside of the 5-6pm window, 3) a travel rebate when they avoided this window 4) a note pledging to make a $5 contribution to charity when they avoided the 5 to 6pm window.	The study found a 17.5% reduction in Red Line Commuters between 5-6pm when the CAT offered $2.25 travel rebate. Out of all of the treatments in the experiment, the most effective treatment was presenting commuters with a rebate for avoiding peak times.
	Seattle's One Less Car Challenge[88] Methods Longitudinal Correlational Behavioral Outcome Reducing SOV commutes	Families in Seattle with more than one car opted-in to commit not to use their additional car for 6-8 weeks during the study. In total, 86 households participated, and study organizers gave each household $80 for participating.	Across participating households, the number of miles families commuted per week by SOV commutes dropped 27%, bicycle miles increased 38% and mass transit commuting miles increased 25%. Carpooling also increased 23% and walking miles increased 30%. In total, 26% of households got rid of their additional car once the study ended.
	Florida DOT[89] Methods	Participants were given $5 each time they lowered their total mileage by 20 miles. In one condition, people received	Regardless of the reward received, around 50% of members in both

	Longitudinal Experimental <u>Behavioral Outcome</u> Reducing driving miles	the reward *after* lowering their mileage. In another condition, people received the reward *before* saving mileage.	conditions reduced their mileage at some point during the study.
Prize Incentives	Non-financial incentives can also be used to motivate commuting behavior. Such incentives are often provided to employers in attempts of reducing SOV-use, or to shift employees' behavior from off-peak hours to reduce congestion and simultaneous demand for transportation.		
	Metropia Application[90] <u>Methods</u> Longitudinal Correlational <u>Behavioral Outcomes</u> Reducing Peak Congestion	Metropia is a phone app that seeks to alter commuters' travel habits by providing rewards for traveling during "off-peak" travel times. Metropia can also deliver personalized nudges and incentives, and offers carpooling. By traveling at 8:30am (instead of 7:30am) and 5:15pm (instead of 4:15pm) commuters were given 100 points compared to only 10 points for those who continued to travel during peak hours.	Participants who were given points were 13% less likely to take a trip during morning rush hour and 7% more likely to commute during an alternative time in the morning.
Employee & Public Benefits	Employers often choose to incentivize employees to use non-SOV commute modes by offering free or discounted passes, bikeshare memberships, or vanpool subsidies. Sometimes transit authorities offer discounts for individuals who join special programs to increase ridership.		

	Travel Benefits & Mode Choice, New York and New Jersey[91] <u>Methods</u> Cross-sectional Correlational <u>Behavioral Outcomes</u> Commute Mode	This study looked at the commuting behavior of nearly 20,000 households in New York and New Jersey. In this study, researchers tracked the efficacy of employer-provided commuter benefits.	Employees who were given transportation benefits by their employers were 9 times more likely to use transit over driving alone. Employees with bike-related benefits were 50 times more likely to commute by bike compared to employees with non-bike-related benefits. Parking benefits also undermined employees' willingness to commute by transit, bike, or by walking.
	Access MIT[92] <u>Methods</u> Longitudinal Correlational <u>Behavioral Outcomes</u> Parking Pass Purchase Parking Lot Usage	This study aimed to reduce faculty and staff use of campus parking. As part of this program, MIT implemented changes to parking policies that included offering free transit passes, higher subsidies for commuter rail trip costs, and supporting half of the cost of parking at public transit facilities.	Since the initiative started, there has been a 15% drop in year-round parking permits and a 10% drop in parking transactions from campus parking lots.
	Atlanta Household Survey[93] <u>Methods</u> Cross Sectional Correlational <u>Behavioral Outcomes</u>	The study examined data from the Atlanta Regional Household Travel Survey and looked at the role of transit passes on transit use among employees.	In this study, when employees received a "free or subsidized transit pass" from their employer, they were 156% more likely to use transit.

	Self-reported Transit Use		Similarly, when employers had access to "free or subsidized parking" self-reported transit use fell 71%.
	NECO Pass Initiative[94] <u>Methods</u> Longitudinal Correlational <u>Behavioral Outcomes</u> Self-reported SOV use	Denver Residents were able to register for the NECO Pass initiative, which enabled citizens to access transit for as little as $100 to $200/year. The city studied how eligibility for these passes shaped transit use.	The City of Boulder reported a 7.7% drop in SOV use between 1990 to 2015 as compared to national trends of transportation use. These data provide suggestive evidence that the pass reduced SOV use.
Other Incentives	Other incentives have been designed to shift mode-use that do not fall squarely into the categories of cash or non-cash incentives.		
	FlexPass at UC, Berkeley[95] <u>Methods</u> Experimental Longitudinal <u>Behavioral Outcomes</u> Parking use	UC Berkeley launched the FlexPass program, which gave participants the ability to report whether they used the campus parking lot or whether they had opted to use an alternative transportation option. In response to their self-reported responses, participants could receive rebates as rewards, to cover the cost of their campus parking permit.	In this study, there was a 4.2% drop in parking demand among people who were assigned to the treatment group (and were offered awarded rebates) as compared to a control group that was not offered awarded rebates.
	Intrinsic Interest in a Driving Reduction Challenge[96] <u>Methods</u> Experimental	In one study, participants were assigned to one of three conditions during a citywide drive-alone challenge. These messages were designed to encourage intrinsic motivation to sustain non-SOV	Although there were no differences in non-SOV commutes by condition, this study suggested that motivations for participating in the study influenced

	Longitudinal <u>Behavioral Outcomes</u> Self-reported motivations Self-reported behavior	commute behavior during a challenge period. Participants were either assigned to receive messages related to cognitive elaboration, cognitive dissonance, or social marketing models.	self-reported commuting behavior and motivations for SOV-commutes.

Table 2. Example of Behavioral Map Strategy

What is a Behavioral Map?	
	- It is a visual of every behavioral step corresponding to the behavior occurring - It is a visual of the assumed barriers of that journey
Steps of a Behavioral Map	
1. Identify Key Behaviors	- What do you want the user to do?
2. Map the Process	- What individual steps do people have to do to achieve the key behavior? - Add relevant statistics about the behavior and actions customers must take - Add relevant barriers to each step leading to the key behavior
3. Talk to People	- Interview customers about the process to find overlooked steps and barriers - Interview employees involved in the journey about touchpoints
4. Test the Solution	- Try to enact the process yourself - Watch people trying to enact the process you are hoping to change
Example of a Behavioral Map	
1. Identify Behaviors 2. Map the Process 3. Rapid Prototyping 4. Test the Solution	1. Increase bus ridership as a means of getting to and from campus for classes among college students at a large public university. 2. Talked to local stakeholders to consider challenges to alternative transportation use through focus groups. After identifying possible solutions such as personalized route tools and changes to the parking permit process (as identified in the literature review described in this paper), we proceeded to Steps 3 and 4. 3. We decided to implement personalized travel plans. After making this decision, we ensured that the planning tool was working as expected. We conducted 17 interviews with transportation and behavioral science experts to work through the prototype and collect feedback. We also completed testing sessions with ~17 students who received the tool to work through potential issues. This phase ended with a working version of the personalized route planning tool. 4. We then ran a field experiment to test the effectiveness of the personalized route planning tool. For data collection, we randomly assigned some students to create a personalized route plan and respond to questions about their commuting behavior (treatment group). Other students completed only questions about their commuting behavior (control group). For full study details see Table 3.

Table 3. Solutions We Have Tested/Are Testing

Our team's ongoing partnerships with cities, transportation initiatives and organizations to promote sustainable commutes. See https://osf.io/ufcht/ for study materials and interim results for all studies.

Partner & Description	Study Description	Population	Psychological Barriers Addressed	Hypotheses	Behavioral Outcome	Results
A mid-sized university in the South	Encourage alternative modes of transportation by using a personalized route tool coupled with follow-up reminder emails. Study Type Randomized Control Trial Personalized Route Plan Timely Reminders	~*N*=3,797 individuals living in and around the university	Intention-action gap: People want to use alternative modes but often do not follow through. Overconfidence: Without making concrete plans and clear intentions, people fail to perceive barriers to shift behavior. Opportunity Cost & Loss Aversion: People fail to recognize the benefits of alternative modes of transportation leading people to feel that changing their behavior is a cost (vs. a benefit).	The personalized route tool makes alternative transportation feel easier than usual. The personalized route tool highlights the benefits of sustainable transportation for money-saved, calories burned, and emissions not burned, thus making alternative modes more attractive.	Self-reported transportation behavior. Actual bus ridership.	The personalized route tool did not lead to a statistically significant reduction in self-reported drive alone trips. The personalized route tool plus follow-up emails did lead to a statistically significant reduction in self-reported drive alone behavior of 7.2% points during the3 month study. This result was statistically significant. There was no significant difference in the number of bus trips taken between study conditions.

City of Austin	Encourage alternative modes of transportation by using a personalized route tool and a commuter commitment contract. Study Type Randomized Control Trial Personalized Route Commitment Contract	~*N*=1,000 individuals living around Austin, Texas	Intention-action gap: People want to use alternative modes but do not follow through. Overconfidence: Without making concrete plans and setting clear intentions, people fail to perceive barriers to shift behavior. Opportunity Cost & Loss Aversion: People fail to recognize the benefits of alternative modes of transportation leading people to feel that changing their behavior is a cost (vs. a benefit).	The personalized route tool and commitment contract will make alternative transportation feel easier than usual. The personalized route tool highlights the benefits of sustainable modes of transportation for money-saved, calories burned, and emissions not burned, thus making alternative modes more attractive. Asking people to commit to behavior change, and reminding them of these commitments, will increase the salience of the desired behavior, and encourage follow through.	Self-reported transportation behavior. Actual bus ridership. Actual parking data.	Results are in progress.
City of Durham	Encourage alternative modes of transportation by using a personalized route tool and lottery-based incentives. Study Type Randomized Control Trial Personalized Route Commitment Contract Random Lottery Rewards	*N*=1,496 people living in and around Durham, NC	Intention-action gap Friction costs associated with figuring out how to commute in a different way. Present Bias: Neglecting the opportunity costs of driving and failing to see to see the	The personalized route tool will make alternative transportation easier than it usually is. Furthermore, the personalized route tool highlights the benefits of sustainable modes of transportation for money-saved, calories	Self-reported transportation behavior; Actual bus ridership data.	The personalized route tool lead to a statistically significant reduction in self-reported drive alone behavior (9% reduction over the first ~2 months of the study). The bus lottery did not lead to a further decrease in drive alone behavior.

			benefits of alternative modes of transportation.	burned, and emissions not burned. Lastly, the lottery incentive capitalizes on the fact that people overweight small probabilities. Together, the personalized route plans and lottery incentive should increase the attractiveness of sustainable transportation behaviors.		Additional analyses on bus ridership are still being analyzed but are currently showing consistent results.
Portland Oregon Bureau of Transportation ("BIKETOWN")	Encourage users to refer other people to use a new bikeshare program by sending targeted emails. Study Type: Randomized Control Trial Framing/Messaging	*N*=45,947 members of Portland's bike share program.	Friction costs associated with referring friends. Default of not speaking to friends about commuting.	By increasing the benefits of referral this will ease the perceived cost of referring friends and help users overcome the status/quo default of not communicating transportation choices.	Successful referral to the bikeshare program	People were 3x more likely to refer a friend when they had the chance to receive an incentive ($5 credit for BIKETOWN) than when they could donate the $5 incentive to charity (0.78%) vs. (0.26%). This result was statistically significant.
Oregon Department of Transportation "ODOT"	Encourage users to switch from one carpool matching tool to another new tool through the use of autoenrollment or by sending a targeted email. Increase the usage of the new carpooling tool	*N*=65,910 25,790 active users of the tool	Friction costs associated with registering for the new program.	By increasing the ease of sign-ups to the new tool; (i.e., account already set up vs. new action needed to set up the account) this should encourage sign-ups and usage of the new tool.	Sign up for carpooling tool Subsequent app usage	In the autoenrollment condition 5.9% logged into to the new tool as compared to 3.9% in the control condition. This result was statistically significant.

	Study Type: Randomized Control Trial Autoenrollment	40,120 inactive users				People who had to "take action" to create a new account were more likely to use the app six months later (67% compared to 54%). This result was statistically significant. Long-term analyses are ongoing
San Francisco Municipal Transportation Agency "SFMTA"	Encourage employees to sign up for public transportation benefits by sending targeted messages Study Type: Randomized Control Trial Messaging	*N*=5,926 MTA benefits-eligible employees	Overcome opportunity cost neglect by emphasizing the benefits of carpooling (such as by emphasizing financial savings)	By highlighting the often underrecognized benefits of public transportation this could increase enrollment in transportation benefits among SFMTA employees.	Sign up for benefits program ("WageWorks")	Employees who received a post-card emphasizing the benefits of public transportation (i.e., the financial savings, the time savings, or the increase of control over one's time), were 23% more likely to enroll in the benefits program compared to a control group who received no message (7.4% vs 6.0%). This result was statistically significant. There was no difference in enrollment across treatment groups. Regardless of condition, people were more likely to enroll if they were 1) younger 2) women, 3)

						worked a regular shift, 3) lived closer to transit, and 4) lived further from work.
Santa Monica California	Encourage employees to sign up for an existing carpooling program by sending targeted messages Study Type: Randomized Control Trial Messaging	~*N*=2,800	Overcome opportunity cost neglect by emphasizing the benefits of carpooling (such as by emphasizing financial savings) Overcome friction of finding a carpooling match by using a technology platform to automatically match individuals from the same organization with one another.	By highlighting the underrecognized benefits of carpooling this could increase enrollment in carpooling benefits among employees.	Sign up for the carpooling matching service Ridership data	This study is on hiatus—stopped at the design phase—due to COVID.
Technology Platform	Encourage existing users of the Carpooling App to refer new users Study Type: Messaging	*Varies; available by request*.	Overcome friction by helping users see the benefits of the referrals for their friends and family in terms of saving time and money Highlight loss aversion by emphasizing that riders lose out not by referring friends.	By helping users see the benefits to their friends in terms of "giving the gift of time or money" they might be more likely to refer their friends. By highlighting the fact that referring friends could give them $20 in credit for the service or for a charity of their choice this could make	Referrals made Ridership data	This study is on hiatus—stopped at the design phase—due to COVID.

				the referral more attractive and encourage friend referrals		
Technology Company	Encouraging new employees to uptake carpooling benefits by sending targeted messages using *dynamic social norms* (i.e., conveying the fact that carpool use and sustainable commuting is an emerging trend). Study Type: Messaging	*N*=15,000 new employees over 5 months	Overcome inertia and status quo bias by encouraging new employees to change their habits during a critical moment of change (i.e., when they are transitioning to a new workplace).	By encouraging new employees to take up a carpooling service (and other possible transportation modes) this could encourage employees to build habits around transportation.	Carpooling use Parking data	This study is on hiatus—stopped at the implementation phase—due to COVID.
Western Washington University Bellingham, WA	Encourage employees to sign up to a new carpooling program by sending targeted messages and reminders Study Type: Messaging	~*N*=3,500 faculty, staff, and students	Overcome opportunity cost neglect by emphasizing the benefits of carpooling Overcome the availability bias of sustainable commuting seeming under-subscribed or negative by asking the university leader and staff to share their positive experiences with carpooling	By highlighting the underrecognized benefits of carpooling this could increase enrollment in carpooling benefits among employees. By having these messages come from the university leader and feature members of the university, this could help change perceptions of sustainable transportation activities	Sign up for the carpooling matching service Ridership data	This study is on hiatus—stopped at the initial implementation phase—due to COVID.

Private Companies – These Studies are on Hiatus Due to COVID.

San Francisco, CA - Biotechnology company	15,000 employees	- New employee study encouraging sign-ups to carpool via email - Testing incentives (in partnership with Scoop) - Exploring wellbeing before and after carpool uptake
Mountain View, CA - Large software company	2,500 employees	- Encourage reduction of SOV and employee uptake of long-distance shuttles from San Francisco to office (area lacks strong public transit option) - Testing incentives and incentives framing (in partnership with Waze)
Bay Area, CA - Large software company	1,600 employees	- Testing incentives and incentives framing (in partnership with Waze)

Commuting Platforms (Technology Partners) – These Studies are on Hiatus Due to COVID.

RideAmigos - Online commute planning platform for organizations	Varies	- Encourage carpool sign-up - Encourage existing users to carpool more
Scoop - Carpool/rideshare matching app	Varies	- Encourage carpool sign-up - Exploring wellbeing before and after carpool uptake
Luum - Integrated parking software	Varies	- Testing daily, monthly, incremental parking
Waze - Carpool/rideshare matching up	Varies	- Encourage carpool usage in existing users - Testing message framing - Testing incentives framing

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