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review

Nudging the commute: Using behaviorally informed interventions to promote sustainable transportation

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abstract

One way to limit the emissions from fossil fuel combustion that underlie global climate change and air pollution is to nudge people away from commuting alone in their vehicles—that is, to gently encourage people (without limiting their freedom of choice) to replace single-occupancy-vehicle commutes with environmentally friendlier options. Abundant research has focused on the influence of external factors—for example, urban design, the availability of roadways and bicycle lanes, and the costs of using one's chosen means of transportation—on commuters' transportation decisions. Much less is known about the psychological factors that influence which commuting modes people use. The field of behavioral science is therefore overdue to focus on transportation. In this article, we—a multidisciplinary team consisting of academics, applied researchers, and a transportation-management consultant—present a framework for designing and testing interventions informed by behavioral theory. We hope that this framework will help policymakers in government and the private sector identify nudges that can encourage commuters to adopt eco-friendlier modes of transportation. We also describe several studies we have designed on the basis of this framework and present the results collected so far.

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Core Findings

What is the issue?
Single-occupancy-vehicle (SOV) commutes are a significant contributor to global emissions. While *structural* interventions focus on reducing SOV commutes by changing economic incentives or modifying the physical environment, less is known about relevant *behavioral* factors. Knowing the psychological levers for shifting people's commuting mode choices has the potential to result in more effective interventions.

How can you act?
Selected recommendations include:
1) Highlighting the easily hidden costs of driving and the often-hidden benefits of alternative commuting modes
2) Ensuring that making the switch from SOV commutes to using alternative commuting modes seems easy and attractive
3) Delivering psychologically informed interventions in combination with structural interventions

Who should take the lead?
Transportation managers, government policymakers, and business leaders

To avoid the most expensive and catastrophic effects of global climate change and air pollution, humanity must dramatically reduce the emissions associated with fossil fuel combustion. Researchers predict that if emissions of greenhouse gases, such as carbon dioxide, continue at their current pace, global temperatures could rise to 8°F above preindustrial levels by the year 2100.[1] This warming will cost about $400 billion each year in the United States alone, which is 1.25 times the amount currently spent on heart disease, the leading cause of death.[1] The temperature increase is also projected to cause calamitous human suffering and ecological collapse. More than a million plant and animal species are at risk of extinction.[2] In 2017, a large collaboration of scientists warned that the world could endure "widespread misery" resulting from climate change.[3] People are already suffering because of the emissions responsible for air pollution, as is highlighted by the COVID-19 pandemic: Individuals who live in areas with high levels of air pollution are more likely to die when exposed to the virus.[4]

Recent estimates suggest that the transportation modes people use significantly affect emission levels.[5] In a 2019 report, the U.S. Environmental Protection Agency (EPA) noted that driving and air travel were responsible for about 27% of greenhouse gas emissions in the United States each year.[6] The EPA also reported that motor vehicles accounted for 75% of carbon monoxide pollution and one third of the air pollutants that produce smog.[7] In a typical prepandemic workweek, about 128 million people in the United States—86% of workers—commuted to their jobs by car, and over three quarters of this group drove solo. In the transportation industry, driver-only trips are known as single-occupancy vehicle (SOV) commutes.[8,9]

To slow global climate change over the next 20 years, massive numbers of people must change their commuting behavior to reduce SOV commutes and to increase the use of other commuting modes. With 15% of U.S. carbon emissions and 24% of global carbon emissions stemming from car use,[10] it is difficult to imagine a successful climate change mitigation strategy that does not include encouraging commuters to increase their use of eco-friendly modes of travel.

Reduced driving could also have financial benefits for municipalities and individuals. Each of the 4.18 million miles of road in the United States 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 the potential benefits of shifting away from SOV commutes, how can transportation managers, government policymakers, and business leaders encourage individuals to adopt more environmentally sustainable commuting modes? In this article, we describe standard approaches to the problem, explain why we believe that adding strategies informed by behavioral science research could increase the adoption of greener commuting modes, and present a framework for identifying behaviorally informed interventions that are likely to be effective. Our views are based on theory as well as experiments we have conducted.

In another article recently published by *Behavioral Science & Policy,* Christine Kormos and her colleagues similarly argued that behavioral science research has untapped potential for reducing SOV commutes.[13] Their article provides a broad overview of previously conducted behavioral science research related to three kinds of interventions: communication-based approaches, bias-busting approaches, and technology-based approaches. In our article, we delve more deeply into the identification of behavioral barriers that prevent people from changing their daily commuting modes. On the basis of our experiences, we also provide a how-to guide for forming partnerships between behavioral scientists and transportation management professionals, present our own experimental results, and offer tactical tips for policymakers who want to implement behavioral science–based strategies to reduce SOV commutes.

Past Strategies & New Opportunities for Changing Mode Choice

Researchers and policymakers have developed an approach known as *transportation demand management* (TDM) to encourage sustainable commuting and minimize SOV traffic. *Sustainable commuting* usually refers to using environmentally friendly commuting modes, such as taking public transportation (bus, subway, light rail, tram), walking, cycling, or carpooling. Designers of TDM strategies aim to increase the use of sustainable commuting modes by enacting policies, programs, and pricing that make these modes more appealing, convenient, and accessible.[15]

Over the past 30 years, researchers and policymakers have tested various TDM methods to promote sustainable commutes. These methods generally fall into two categories.[15] *Structural* interventions focus on changing economic incentives or modifying the physical environment, such as by closing roads and replacing them with bicycle lanes. *Behavioral* interventions focus on psychology, such as by changing attitudes, beliefs, values, and the perceptions of norms that relate to transportation choices.

Most researchers have focused on structural interventions and examined the effects of land use,[16] the availability of public transit and parking infrastructure,[17–19] parking pricing,[20] congestion pricing,[21,22] and trip length,[23] among other variables, on commuting behavior. (For a comprehensive review, see reference 24.) This research is certainly valuable. Yet studies demonstrating the effectiveness of behavioral interventions could provide powerful tools for increasing the public's adoption of sustainable commuting modes. After all, such interventions have had far-reaching success in other domains, such as public health and education.[25,26]

Unfortunately, researchers are not yet sure whether applying behavioral interventions can encourage commuters to shift from SOV commutes to other commuting modes.[27] Most research on mode shifts has been published by transportation researchers, not psychologists.[28] Moreover, behavioral scientists have historically overlooked the topic, aside from examining how consumers decide to purchase fuel-efficient vehicles.[26,29] Relatively little research has addressed questions such as how people determine whether to drive to work or take public transportation. (For similar arguments on the need for more research into behavioral interventions, see reference 27.)

Research into the effects of various psychological levers for shifting people's commuting mode choices is growing but still nascent. Much of this work has relied on correlational data as opposed to evidence from experiments, which can establish cause and effect more convincingly.[30–32] Notably, in a meta-analysis published in 2020 that combined data from 2,920 studies and explored the effects of psychologically informed interventions on commuting modes,[28] only 30 of the included studies used randomized controlled trials (RCTs). RCTs randomly assign participants to experimental and control groups and are considered the gold standard for determining whether an intervention has had the desired effect. What is more, only two of the studies in this meta-analysis relied on objective measures, such as GPS data, to assess the effect of the interventions on commuting behavior. Other meta-analyses of studies on this topic describe a similar lack of causal evidence and overreliance on self-reported data.[33,34]

Because of the successes that behavioral interventions have achieved in other domains, these practices have drawn the interest of policymakers who want people to switch from SOV commutes to other commuting modes.[25,26] To better understand the efficacy of behavioral interventions[28] and overcome the limitations of correlational and self-report studies,[35] we decided to collaborate with multiple businesses and city agencies to conduct an array of mostly RCTs aimed at influencing commuting mode choices.

We are a multidisciplinary team consisting of academics, applied researchers, and a consultant who works with cities and organizations to implement TDM methods. Our multidisciplinary,

collaborative approach fits with an emerging focus in behavioral science on understanding how to use psychologically informed interventions to effectively change behavior at scale.[36] The effective application of behavioral interventions requires both an understanding of behavioral science principles and knowledge of the practical aspects of program design.

Preliminary Research Planning

To carry out our research, we first needed to find organizations that would partner with us to study the effect of behavioral science interventions on their constituents' commuting modes. One of the authors, Jessica Roberts, is a principal at Alta Planning + Design, a consulting firm that advises public agencies and organizations on TDM programs and research. With her organization's assistance, we invited public agencies and private companies in the United States to submit a brief statement of interest if they wanted to collaborate with us on behavioral research exploring ways to encourage people to shift from SOV commutes to using sustainable commuting modes. We specifically asked about their interest in encouraging carpooling, because we knew that some of our prospective partners would have technology that could provide objective data on carpooling before and after an intervention was introduced. To be clear, by *carpooling*, we mean having riders who are traveling between the same two locations ride in the same vehicle; usually carpooling involves people commuting to work, but newer technology is also enabling more spontaneous carpooling for one-off trips. We were also open to studying other commuting mode shifts. Our recruitment materials may be found at the Open Science Framework (https://osf.io/ufcht/).

This call to action yielded 36 interested parties. We were able to work with five parties that represented organizations and institutions running transportation initiatives and technology platforms that had developed carpooling tools.

We were also able to work with 12 partners through a collaboration with the Center for Advanced Hindsight at Duke University.

Because we were working with partners that needed to control their costs, we concentrated the research on behavioral interventions that did not involve monetary rewards. We do not mean to imply that financial incentives are ineffective. Case studies from jurisdictions across the United States show that cash and cash-like rewards such as lottery entries can motivate commuting mode shifts. See Table 1 for examples of studies using such rewards.

Although many people claim that they want to commute less by car, they often have difficulty following through on these intentions, especially when trying to change the way they habitually commute.[27,37] Thus, even before we put out the call to potential research partners, we conducted a review of behavioral science research to identify the psychological barriers likely to prevent individuals from relinquishing their SOV commutes in favor of other commuting modes. We later required all partners to study interventions meant to overcome one or more of the barriers listed next.

Behavioral Barriers to More Sustainable Commutes

Some of the barriers we describe in this section are similar to and can exacerbate one another. We address them separately because overcoming them can sometimes require different intervention strategies.

Barriers to Considering a Change in Mode

Availability Bias. People tend to think that examples that easily come to mind are more representative of a situation than they actually are.[38] Because the popular media glorifies driving, the most easily accessible images of driving depict prestige and freedom.[39] In contrast, alternative forms of transportation, such as riding the bus, are frequently portrayed as being difficult, dirty, and unsafe.[40] Exposure to glorified images of driving and negative portrayals of other options can bias people against biking to work or using mass transit.[41] In another manifestation of availability bias, people often overestimate the occurrence of rare events such as childcare emergencies because

Table 1. Examples of past U.S.-based studies of incentives for shifting commuting modes

Study	Study type[a]	Desired behavior change	Intervention	Results
			Financial[b]	
BART Perks (San Francisco County Transportation Authority, 2018)	Longitudinal, correlational	Reduced peak congestion	The San Francisco Bay Area Rapid Transit (BART) system implemented a rewards program to encourage riders not to use transit during the most popular commuter window. Participants earned points they could use to obtain cash or gift cards during the study.	In the first phase of the study, when 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, when people could earn points to redeem for gift cards by altering their travel time, taking surveys, or using BART in the evenings or to travel to the airport, people were willing to alter their typical commute behavior by 6%–20%.
CAPRI program (Zhu et al., 2015)	Longitudinal, correlational	Reduced peak congestion	The Congestion and Parking Relief Incentives (CAPRI) program provided points and prizes for commuters to avoid peak hours. Commuters chose to receive either 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 with commuters who were not enrolled in the program. These effects were stronger when participants knew someone who had won a prize: Commuters with friends who recently won a prize traveled around 1.5 minutes earlier than their normal travel time.
Chicago Transit Authority Cubs game congestion study (ideas42, 2017)	Longitudinal, experimental	Reduced peak congestion	The Chicago Transit Authority (CTA) wanted to reduce congestion after Chicago Cubs games. To encourage commuters to avoid the Red Line between 5 p.m. and 6 p.m., participants: (a) were sent an alert reminding them of a baseball game, (b) were sent a message encouraging them to use the Red Line outside of the 5 p.m.–6 p.m. window, (c) received a $2.25 travel rebate when they avoided this window, or (d) received a note pledging to make a $5 contribution to charity when they avoided the 5 p.m.–6 p.m. window.	The study found a 17.5% reduction in Red Line commuters between 5 p.m. and 6 p.m. when the CTA offered the $2.25 travel rebate. The most effective incentive was presenting commuters with a $2.25 rebate for avoiding peak times.
Seattle's One Less Car Challenge (Bauer et al., 2018, pp. 31–32)	Longitudinal, correlational	Reduced SOV commutes	Families in Seattle with more than one car opted in to commit not to use their additional car for six to eight weeks during the study. In total, 86 households participated. Study organizers gave each household $80 for participating.	Across participating households, the number of miles families commuted per week by SOV dropped 27%, bicycle miles increased 38%, mass transit commuting miles increased 25%, carpooling increased 23%, and walking miles increased 30%. In total, 26% of households got rid of their additional car once the study ended.
Florida DOT incentive study (Lee et al., 2013)	Longitudinal, experimental	Reduced driving miles	Participants were given $5 each time they lowered their total mileage by 20 miles. In one condition, people received the reward after lowering their mileage. In another condition, people received the reward before saving mileage.	Regardless of the reward received, around 50% of members in both conditions reduced their mileage at some point during the study.

(continued)

Table 1. Examples of past U.S.-based studies of incentives for shifting commuting modes (*continued*)

Study	Study type[a]	Desired behavior change	Intervention	Results
			Prize incentives[c]	
Metropia application (Bauer et al., 2018, pp. 7–9)	Longitudinal, correlational	Reduced peak congestion	Metropia is a phone app used 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 carpool matching. By traveling at 8:30 a.m. (instead of 7:30 a.m.) and 5:15 p.m. (instead of 4:15 p.m.), commuters earned 100 points per trip compared with only 10 points given to those who continued to travel during peak hours.	Participants who were given points were 13% less likely to take a trip during the morning rush hour and 7% more likely to commute during an alternative time in the morning. (The points could be exchanged for discounts, offers, or other goods or services offered by Metropia.)
			Employee & public benefits[d]	
Travel benefits and mode choice, New York and New Jersey (Bueno et al., 2017)	Cross-sectional, correlational	Changed commute mode	This study looked at the commuting mode used by nearly 20,000 households in New York and New Jersey. 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 rather than driving alone. Employees with bike-related benefits were 50 times more likely to commute by bike compared with employees with non-bike-related benefits. Parking benefits undermined employees' willingness to commute by transit, bike, or walking.
Access MIT (Massachusetts Institute of Technology Office of Sustainability, n.d.)	Longitudinal, correlational	Reduced parking pass purchase; reduced parking lot usage	This ongoing study aims 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 paying 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 at campus parking lots relative to baseline.
Atlanta Regional Household Travel Survey (Ghimire & Lancelin, 2019)	Cross-sectional, correlational	Increased self-reported transit use	The study examined data from the Atlanta Regional Household Travel Survey and looked at the role of transit passes on transit use among employees.	Employees who received a free or subsidized transit pass from their employer were 156% more likely to use transit. Similarly, when employers had access to free or subsidized parking, self-reported transit use fell 71%.
ECO Pass Initiative (Regional Transportation District, n.d.)	Longitudinal, correlational	Reduced self-reported SOV use	Denver residents were able to register for the ECO Pass initiative, which enabled citizens to access transit for as little as $100–$200 a year. The city studied how eligibility for these passes shaped transit use.	The City of Denver reported a 7.7% drop in SOV use between 1990 and 2015 as compared with national trends of transportation use. These data provide suggestive evidence that the pass reduced SOV use.

Study	Study type[a]	Desired behavior change	Intervention	Results
			Other incentives[e]	
FlexPass at the University of California, Berkeley (Tang et al., 2016)	Experimental, longitudinal	Reduced parking on campus	UC Berkeley launched the FlexPass program, which gave students and faculty the ability to report whether they used the campus parking lot or an alternative transportation option. In exchange for their reports, 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 (the group offered rebates) as compared with a control group that was not offered rebates.
Intrinsic interest in a driving reduction challenge (Kent de Grey et al., 2018)	Experimental, longitudinal	Increased self-reported motivation to reduce SOV commutes; reduced self-reported SOV commuting	In one study, participants were assigned to one of three conditions during a citywide drive-alone reduction challenge. These messages were designed to encourage intrinsic motivation to sustain non-SOV commutes during a challenge period. Participants were assigned to receive messages based on one of three theories about motivation: cognitive elaboration, cognitive dissonance, or social marketing.	Although there were no differences in non-SOV commutes by condition, this study suggested that motivations for participating in the study influenced self-reported commuting behavior and self-reported motivations for SOV commutes.

Note. SOV = Single-occupancy vehicle.

[a] *Longitudinal studies* follow people over time. In doing so, they provide a more accurate snapshot of long-term behavior change than other approaches do. These are chosen when it is possible to track people's behavior and when there is a need to examine a sustained change on behavior. *Correlational studies* examine the relationship between two or more variables and often examine associations over time. Correlational studies cannot establish causality and thus provide only tentative evidence for a causal relationship. *Experimental studies* assign study participants to groups randomly and can reveal whether an intervention or interventions cause any changes in the desired outcome. This method is selected when it is necessary to demonstrate causality and when it is possible to randomize and track participants.

[b] Financial incentives such as cash rewards can be used to motivate people to alter the way they commute and are often provided to employees to reduce SOV use or shift employees' behavior from commuting during peak hours to commuting during off-peak hours.

[c] Cash-like incentives such as lottery prizes are often provided with the same aims as financial incentives.

[d] Employers often 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.

[e] Other incentives that do not fall squarely into the categories of cash or noncash incentives have been designed to shift commuter behaviors.

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"people often overestimate the occurrence of rare events"

these events are more memorable. As a result, they may place more value than is warranted on having the flexibility that driving their own car to work allows.

Commute Impedance. People often suffer psychological distress when efforts to reach a goal are thwarted. Anything that reduces the ease of a commuter's trip—like traffic on the way to a destination—can be thought of as *commute impedance*. According to a theory known as the *commute impedance model*,[42] drivers often take a dim view of alternatives to single-occupancy commutes because they fear that these commuting modes will be more unpredictable and that they will have less control over the speed, comfort, and other features of the trip.[43] Research suggests that alternative modes of transportation are, indeed, often seen as less desirable than driving one's own car because they are perceived to offer less control and less freedom and are seen as reflecting lower status.[40,44]

Loss Aversion. People dislike losses more than they like equivalent gains, and this *loss aversion* means that people are more likely to avoid risk than to take a potentially beneficial action. Thus, they will often continue with a current behavior unless the threat of a loss motivates them to change.[45] Likewise, when an individual is deciding which mode of transportation to use, the anticipated downsides, or *losses*, of selecting alternative modes could loom larger than the potential benefits in the individual's mind. For example, the anticipated stress of lost independence or having to wait an unpredictable amount of time for a bus may outweigh the anticipated pleasure of being able to relax on a bus instead of sitting behind the wheel in traffic.

Opportunity Cost Neglect. When making decisions, people fail to consider the opportunity costs—the sacrifices they are making by selecting one choice over another.[46–48] With respect to driving, each trip has costs that often go unnoticed, such as tolls collected electronically or parking fees deducted from a paycheck. When people forget about the costs of SOV commutes, this neglect can prevent behavior change.

Present Bias. People tend to minimize the value of future events and outcomes and prioritize the present.[49] Driving is more convenient and familiar than other commuting modes, and the health and environmental benefits of sustainable commuting modes can take years to observe. Hence, even though the ultimate benefits may greatly outweigh the value of immediate convenience, present bias can be a substantial barrier to adopting sustainable modes of transportation.[50]

Status Quo Bias. People are reluctant to change their behavior from an established reference point and therefore need to have strong motivation to overcome their inertia.[45] When it comes to commuting, status quo bias is exacerbated by daily travel routines that have become deeply ingrained habits. Most people drive to work and do it automatically, with little thought. If they are prodded to alter this habitual behavior, they may resist in part because they are likely to mainly consider the downsides of changing their commute.[51]

Sunk Cost Bias. Individuals feel particularly committed to actions in which they have already invested time, money, and effort.[52] Most car owners have already made an up-front investment to purchase their vehicle or pay for an annual parking permit—sunk costs that encourage them to drive even when they could plausibly commute via other modes.[53]

Together, these barriers suggest that to encourage people to consider shifting away from SOV commutes, behaviorally informed interventions need to (a) highlight the easily hidden costs of driving and the often-hidden benefits of alternative commuting modes and (b) ensure that making the switch from SOV commutes to using alternative commuting modes seems easy and attractive. For example, to increase the attractiveness of carpooling or public transportation for people who overestimate how much

they will be inconvenienced by rare events, employers could offer free Uber rides when emergencies arise to provide these people with a sense of a safety net.

Barriers to Actually Adopting a New Transportation Mode

We also observed several psychological mechanisms that could influence whether people follow through on intentions to shift their commuting behaviors. These barriers are especially important for policymakers to consider because commuters often claim that they are interested in taking the bus, walking, or biking to work, yet very few follow through on these intentions[27]—a disconnect often called the *intention–action gap*.

Default Bias. People tend to stick with options that are preset as defaults. For instance, if a company offers free or subsidized parking as a default benefit and requires employees to complete paperwork to obtain a rebate for public transportation, the employees are likely to take the default option and drive to work. 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 tend to avoid difficult decisions and do whatever requires the least amount of effort—that is, whatever presents the least *friction*.[54] Unless people clearly see the benefits of sustainable transportation, they may be deterred by the aspects that make it seem difficult, such as weather or unpredictability.[55]

Overconfidence. People believe in their abilities more than past performance would warrant.[56] They also think that they will have more time to change their behavior than they do in reality and underestimate the amount of effort needed to follow through.[57] This overconfidence can prevent people from commuting in sustainable ways. If individuals say they are going to commute by bike but do not think through the barriers that could prevent this action, like rain, they are likely to quit when they encounter any difficulty.[58] Even if individuals do commit to changing their behavior, they might indefinitely delay acting on the decision.[59]

"overconfidence can prevent people from commuting in sustainable ways"

Social Norms. Actions are influenced by people's beliefs about what other people do (*descriptive norms*) or their beliefs about what others think they should do (*injunctive norms*). Most Americans believe that other people travel to work by SOV commutes, which is based on a descriptive norm that is true in most of the United States.[60] Many cities lack pro-environmental norms that could prompt sustainable behavior.[61] Additionally, stigma is attached to alternative transportation modes, which the public associates with a social status lower than that associated with driving.[62]

These barriers suggest that to encourage follow through on peoples' intentions to change their commuting modes, program designers need to cultivate positive norms around sustainable transportation. Norm shifts might be achieved by increasing the visibility of people's use of these modes and decreasing the visibility of driving. Program designers also need to help people to easily overcome possible obstacles such as rain and service outages.

Although we focus on psychological barriers in this article, we do not mean to imply that structural and practical barriers are unimportant deterrents to the widespread use of alternative commuting modes. For example, lack of knowledge about the existence and benefits of such alternatives can be a deterrent, as can lack of knowledge about the financial and health benefits of alternative commuting modes.[59]

An often-cited barrier against the use of alternative commuting modes is the lack of quality infrastructure. Thus, prior to committing to a partnership with an organization willing to take part in our experiments, we also considered both the availability and the quality of infrastructure at the organization and in the surrounding region.[63]

A Framework for Selecting Organizations & Testing Behavioral Interventions

We used a multistep process for designing and assessing potential interventions. For a summary and fleshed-out example, see Table 2.

Step 1: Partner With Motivated & Mission-Aligned Organizations

In selecting partners from the respondents who initially reached out to us, we prioritized organizations with leaders who expressed a strong interest in our approach, used data-oriented decision-making, and demonstrated an openness to new ideas. We also required potential

Table 2. A framework for designing & testing behavioral interventions

Basic steps in the strategy	Substep	Example of the strategy in action
1. Partner with motivated and mission-aligned organizations.	• Identify an organization interested in the same research problem that interests you. • Form a collaborative working relationship.	We worked with a large public university that wanted to decrease car use in and near campus.
2. Identify and define the unique challenge the organization is facing.	• Conduct kickoff meetings with key stakeholders, including members of senior leadership. • Agree on the specific objectives of the project and timeline. • Figure out exactly what behavior you want participants to change.	Goal: Increase use of buses by students commuting to and from classes by 10% relative to baseline levels.
3. Explore the context and map the psychological barriers to the desired behavior.	• Talk to your research partners and to members of the participant population to identify the individual steps involved in the desired behavior. • List the steps in sequence. • List barriers to each step in the sequence.	After speaking with our partners about the bus routes students might use, we held focus groups with commuter students about the steps and perceived challenges involved in using the bus. We then listed the steps in a diagram along with the barriers that were revealed in the discussions.
4. Design an intervention.	• Guided by the collected findings, design an intervention that seems most likely to overcome the barriers that were identified in the previous step.	Because many students intended to take the bus, ride a bike, or carpool but were not consistent in following through on this intention, we tried to help them follow through by giving them personalized travel plans that demonstrated all the ways they could use these commuting modes. This personalized travel plan tool showed them exactly what route they should take depending on their starting and ending location and exactly how long the commute would take.
5. Pilot test the prototype intervention.	• Try to enact the proposed process yourself. • Watch a small number of people trying to enact the process you are hoping to change. • Revise the plan as needed.	We conducted interviews with transportation and behavioral science experts who critiqued our proposal. We also tried it out ourselves and enlisted 17 students to test out the personalized travel plan tool and provide feedback about which features worked well and which ones did not. In response to the feedback, we made several key changes—for instance, by simplifying the language; reducing the number of travel options; and emphasizing benefits in terms of health, time used, and money saved.
6. Conduct the field study.	• After you have piloted the approach, you can conduct a large-scale field study. • Ideally, you will track objective behavior, such as actual bus commutes taken in relation to the intervention.	We enlisted participants and randomly assigned half of them to the treatment condition. They received the personal planning tool, and we tracked their bus and other commuter mode use. Control participants did not receive the tool. We still tracked the bus use of control participants through a link to their student ID cards; other mode use was tracked using surveys.

partner organizations to have the capacity and willingness to conduct a RCT and to provide behavioral data on the outcomes of the interventions tested. Guided by statistical best practices, we targeted organizations that could provide at least 500 potential participants.[64] To ensure that potential partner organizations demonstrated these qualities, we asked them to answer application questions during an initial phone call. The application questions may be seen at the Open Science Framework (https://osf.io/ufcht/).

Step 2: Identify & Define the Unique Challenge the Organization Is Facing

After this initial phone screening identified an eligible and interested organization, we reviewed the organization's application and entered into a verbal agreement to establish a formal partnership. We then signed a data-sharing agreement with the partner organization and started to collaborate with them to design behavioral interventions. As part of this collaboration, our group conducted kickoff meetings with key stakeholders, including members of senior leadership, and we worked with the partner organization to establish the specific objectives of the project and timeline, including the actions they wanted their constituents to take.

Each partner organization faced different challenges for promoting sustainable commuting modes. At one organization, new employees did not receive clear information about alternative commuting 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 these differences, we worked to identify which psychological barrier identified in our literature review was most relevant to each partner organization.

Step 3: Explore the Context & Map the Psychological Barriers to the Desired Behavior

As an aid to identifying relevant interventions for each organization, we built a *behavioral map*, which (a) visually encapsulates the steps leading up to and enabling a particular behavior and (b) outlines the relevant pain points and psychological barriers that could prevent people from adopting the mapped behaviors. (See a sample map related to carpooling at https://tinyurl.com/yne7rury.) To gather the needed input for these behavioral maps, we tried to observe the experience of mode switching from the commuters' perspectives. To this end, we worked with organizations to conduct open-ended interviews and asked commuters to fill out surveys on the topic. We also analyzed existing data, such as the responses from past surveys that had been conducted by these organizations.

Step 4: Design the Intervention

After designing the behavioral map and considering the psychological processes that posed the greatest barriers to commuters' adopting an organization's desired behaviors, we suggested one or more interventions that would best address those obstacles.

Step 5: Pilot Test the Prototype Interventions

We then worked with our partner organizations to develop prototypes for the chosen interventions. We first piloted the solutions to determine whether the interventions were likely to operate as intended when implemented at scale. For example, when collaborating with a southern U.S. university and developing a prototype for an intervention that provided personalized route planning for public transportation and other alternative commuting modes like biking, we ran a series of group interview 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. Although we tried to craft ideal interventions based on organizational barriers, we also took feasibility into consideration (see reference 35 for an example of an approach to conducting a feasibility analysis).

Step 6: Conduct the Field Study

When steps 1–5 were complete, we launched the studies at scale. Where possible, we designed the studies to be RCTs with objective behavioral outcomes.[35]

86%

U.S. workers who usually commute via car

15%

Car use's share of total U.S. emissions

$100.32b

Total cost to relevant governments for preserving U.S. roads

A Sampling of Our Studies

About half the studies we designed were attempts to increase carpooling. The others focused on increasing public transportation use. Six were completed or are ongoing, but as we write this article, the rest are on hiatus because of the COVID pandemic. See Table 3 for a comprehensive summary of all completed and ongoing projects, and visit the Open Science Framework (https://osf.io/ufcht/) for up-to-date study materials and interim results. On the basis of the findings so far, we are considering ways to improve the effectiveness of the interventions we have tested, apply the interventions to other organizations, and disseminate the results of our ongoing research. Next, we provide a brief overview of the kinds of research we have undertaken.

Carpooling Projects

Several of our behaviorally informed studies rely on messaging to encourage participants to sign up for and use carpooling programs. These messages call attention to typically unrecognized benefits of carpooling. One of our partner organizations had provided little information to new employees about carpooling benefits, so the study we designed with this organization highlighted these benefits, such as opportunities to socialize. In another study, messaging from an organizational leader promoted the (often hidden) benefits of the program for financial savings, physical health (via reduced stress), and environmental sustainability (a core organizational priority). In a subset of these studies, we also formed a joint partnership with ride-matching platforms that allowed us to track actual carpooling behavior.

Among the field experiment studies on hiatus because of the COVID pandemic are projects involving Western Washington University (N = 3,500 employees) and the City of Santa Monica (N = 2,800 employees). While waiting for carpooling projects sidelined by COVID to resume, our team conducted a lab experiment to improve the efficacy of the messages we had designed.

In this online study (N = 642), we instructed participants to imagine that their workplace was starting a carpooling program. Participants in the control group simply read about the program. Participants in the experimental groups were told that the program could provide a benefit, which differed depending on their assigned condition: The program would help them to either get to know their colleagues (the *social* condition), have quiet time (the *personal* condition), save money (the *economic gain* condition), or avoid losing money from driving (the *economic loss* condition). Participants in the economic gain condition expressed the greatest interest in signing up for the carpooling program. In contrast, participants in the social condition showed the least interest in the program. We plan to design and test new interventions in the field as a result of this initial online study.

Projects Promoting the Use of Public Transportation

In two of our completed studies, we aimed to increase transit ridership by providing personalized route plans; one of those studies also tested the impact of a weekly cash prize drawing—that is, a lottery—in addition to the personalized route plans. As described in Table 3, in both experiments, the personalized route plans increased bus use and reduced SOV commutes during the study, according to self-reports. In the lottery study, the effect of personalized route plans was similar to or greater than that of the lottery incentive. This last finding suggests that behavioral interventions alone, without the addition of cash or cash-like incentives, can meaningfully shape commuting behaviors, especially when these interventions make it easy to use alternative transportation modes.

Discussion: Future Directions

In the past few years, we have engaged in countless discussions with policymakers in government and industry, TDM practitioners, and behavioral scientists about how to shift commuting behaviors to reduce SOV commutes, and we have collaborated on designing and implementing field experiments with 17 diverse partners that include city governments, universities, technology companies, and private corporations. The number of

Table 3. Solutions we have tested or plan to test through our team's ongoing partnerships with cities, transportation initiatives, & organizations to promote sustainable commutes

Partner	Study description	Population	Psychological barriers addressed	Hypotheses	Outcome measured	Results
			Randomized controlled trials			
A midsized southern U.S. university	Encourage alternative modes of transportation by using a personalized route tool coupled with follow-up reminder emails.	*N* = 3,797 individuals living in and around the university	Intention–action gap Overconfidence Opportunity cost neglect Loss aversion	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 released, thus making alternative commuting 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 single-occupancy vehicle (SOV) commutes. The personalized route tool plus follow-up emails did lead to a statistically significant reduction in self-reported SOV commutes of 7.2% during the 3-month study. This result was statistically significant. There was no significant difference between study conditions in the number of bus trips taken.
City of Austin, Texas	Encourage alternative modes of transportation by using a personalized route tool and a commuter commitment contract.	≈*N* = 1,000 individuals living around Austin	Intention–action gap Overconfidence Opportunity cost neglect Loss aversion	The personalized route tool and commitment contract will make alternative transportation modes feel easier than usual. The personalized route tool highlights the benefits of sustainable modes of transportation for money saved, calories burned, and emissions not released, thus making alternative commuting 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. This study is on hiatus—stopped after one week—due to COVID.

(continued)

Table 3. Solutions we have tested or plan to test through our team's ongoing partnerships with cities, transportation initiatives, & organizations to promote sustainable commutes (*continued*)

Partner	Study description	Population	Psychological barriers addressed	Hypotheses	Outcome measured	Results
City of Durham, North Carolina	Encourage alternative modes of transportation by using a personalized route tool or the personalized tool plus lottery-based incentives.	*N* = 1,496 people living in and around Durham	Intention–action gap Friction costs associated with figuring out how to commute in a different way. Present bias	The personalized route tool will make using alternative transportation easier than it usually is. Furthermore, the personalized route tool highlights the benefits of sustainable modes of transportation for money saved, calories burned, and emissions not released. 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 using sustainable transportation.	Self-reported transportation behavior Actual bus ridership data	The personalized route tool alone led to a statistically significant reduction in self-reported SOV commutes (9% reduction over the first five weeks of the study). The addition of the lottery did not lead to a further decrease in SOV commutes. Bus ridership data also showed increases in ridership because of the personalized tool; however, these results were based on fewer participants and were less reliable.
Portland, Oregon, Bureau of Transportation (BIKETOWN)	Incentives, described in two different randomly assigned emails, encourage users to refer other people to use a new bikeshare program	*N* = 45,947 members of Portland's bikeshare program	Friction costs associated with referring friends Default of not speaking to friends about commuting	By offering benefits for making a referral, this approach will ease the perceived cost of referring friends and help users overcome the status quo default of not communicating transportation choices.	Referral to the bikeshare program	People were 3 times 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% versus 0.26%). This result was statistically significant.
Oregon Department of Transportation (ODOT)	Encourage users to switch from one carpool matching tool to a new tool through the use of autoenrollment or by sending a targeted email. Increase the usage of the new carpooling tool.	*N* = 65,910 Of those, 25,790 are active users of the tool, and 40,120 are inactive users.	Friction costs associated with registering for the new program	By increasing the ease of sign-ups for the new tool (that is, having the account already set up versus needing to take new action to set up the account), autoenrollment should encourage sign-ups and use of the new tool.	Sign-up for carpooling tool Subsequent app use	In the autoenrollment condition, 5.9% logged into to the new tool as compared with 3.9% in the control condition. This result was statistically significant. People who had to take action to create a new account were more likely to use the app six months later (67% compared with 54%). This result was statistically significant. Long-term analyses are ongoing.

Partner	Study description	Population	Psychological barriers addressed	Hypotheses	Outcome measured	Results
San Francisco Municipal Transportation Agency (SFMTA)	Encourage employees to sign up for public transportation benefits by sending targeted messages.	*N* = 5,926 SFMTA benefits-eligible employees	Opportunity cost neglect	Overcome opportunity cost neglect by highlighting the often underrecognized benefits of public transportation and thus increasing enrollment in transportation benefits by SFMTA employees.	Sign-up for benefits program (WageWorks)	Employees who received a postcard emphasizing the benefits of public transportation (that is, financial savings, time savings, or increased control over one's time) were 23% more likely to enroll in the benefits program compared with a control group who received no message about the benefits (7.4% versus 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 (a) young, (b) women, (c) working a regular shift, (d) living close to transit, and (e) living further from work.
Santa Monica, California	Encourage employees to sign up for an existing carpooling program by sending targeted messages.	≈*N* = 2,800	Opportunity cost neglect Friction costs associated with finding a carpooling match	Overcome opportunity cost neglect by highlighting the underrecognized benefits of carpooling and thus increasing employee enrollment in the carpooling program. Overcome friction costs by using a technology platform to automatically match individuals from the same organization with one another.	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 platform's carpooling app to refer new users.	Varies; available by request	Friction costs associated with referring their friend Loss aversion	Highlighting that referring friends could give them $20 in credit for the service or for a charity of their choice could make the referral more attractive and encourage friend referrals.	Referrals made Ridership data	This study is on hiatus—stopped at the design phase—due to COVID.

(continued)

Table 3. Solutions we have tested or plan to test through our team's ongoing partnerships with cities, transportation initiatives, & organizations to promote sustainable commutes (*continued*)

Partner	Study description	Population	Psychological barriers addressed	Hypotheses	Outcome measured	Results
Technology company	Encourage new employees to uptake carpooling benefits by sending targeted messages using dynamic social norms (that is, conveying the fact that carpool use and sustainable commuting are emerging trends).	*N* = 15,000 new employees over five months	Status quo bias	Overcome inertia and status quo bias by encouraging new employees to adopt new habits during a critical moment of change (such as when they are transitioning to a new workplace).	Carpooling use Parking data	This study is on hiatus—stopped at the implementation phase—due to COVID.
Western Washington University in Bellingham, Washington	Encourage employees to sign up for a new carpooling program by sending targeted messages and reminders.	≈*N* = 3,500 faculty, staff, and students	Opportunity cost neglect Availability bias	Highlighting the underrecognized benefits of carpooling could increase enrollment in carpooling benefits among employees. Having these messages come from the university leader and feature members of the university 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 implementation phase—due to COVID.
			Studies in partnership with private companies			
Biotechnology company in San Francisco, California	Via e-mail, encourage new employees to sign up to carpool. Test incentives (in partnership with Scoop). Explore well-being before and after carpool uptake.	15,000 employees				This study is on hiatus due to COVID.

Partner	Study description	Population	Psychological barriers addressed	Hypotheses	Outcome measured	Results
Large software company in Mountain View, California	Encourage the reduction of SOV commutes and employee uptake of long-distance shuttles from San Francisco to the office (the area lacks a strong public transit option). Test incentives and framing of incentives (in partnership with Waze).	2,500 employees				This study is on hiatus due to COVID.
Large software company in the Bay Area of California	Test incentives and framing of incentives (in partnership with Waze).	1,600 employees				This study is on hiatus due to COVID.
			Commuting platform technology partners			
RideAmigos, an online commute planning platform for organizations	Encourage carpool sign-up. Encourage existing users to carpool more.	Varies				This work is on hiatus due to COVID.
Scoop, a carpool- and rideshare-matching app	Encourage carpool sign-up. Explore well-being before and after carpool uptake.	Varies				This work is on hiatus due to COVID.
Luum, integrated parking software that enables organizations to manage and administer their parking facilities	Test different ways to structure parking pricing: pay daily, pay monthly, pay annually, and pay incrementally (the price increases or decreases with use).	Varies				This work is on hiatus due to COVID.
Waze, a carpool- and rideshare-matching app	Encourage carpooling by existing users. Determine how best to frame messages. Determine how best to frame incentives.	Varies				This work is on hiatus due to COVID.

Note. See https://osf.io/ufcht/ for study materials and interim results for all studies. See the main text for definitions of the psychological barriers.

participants in these experiments ranges from 1,000 to 60,000. Although people working in the TDM field have great interest in increasing the sustainable use of public transportation by applying behavioral interventions, more research is needed to reveal how best to apply behavioral insights and scale interventions to encourage commuters to choose sustainable transportation options. Progress is being slowed by the lack of a reliable funding pipeline to support this work.

So far, the results of our experiments indicate that behavioral interventions can be helpful but are not yet as effective as they could be. Across the studies listed in Table 3, no behavioral intervention resulted in more than a 9% change in how frequently commuters used an alternative to SOV commutes. Additionally, in a recent study involving 60,000 employees in the United Kingdom who lived near public transportation and said they wanted to commute in more sustainable ways, we found no evidence that behaviorally informed interventions reduced SOV commutes.[27] In many circumstances, such as when SOV commutes are the easiest and cheapest commuting option, behavioral interventions alone are unlikely to provide enough of a nudge to spur increased use of more sustainable commuting modes.

To encourage commuting mode shifts, policymakers and employers will need to deliver psychologically informed interventions in combination with structural interventions, such as offering financial incentives as well as imposing higher costs for parking and SOV commute tolls during rush hour. When considering how best to proceed, researchers and program designers need to consider the entire decision-making context, ensuring that existing policies and programs—such as subsidies for commuting expenses, pricing for parking, and congestion pricing schemes—are aligned with the goal of increasing the use of sustainable transportation. In our experience, such alignment is essential for a behaviorally informed intervention to have a chance of working.

Building on this insight, we are currently exploring how employers might restructure the way they charge for parking at the office. In one behaviorally informed financial intervention, we are separating bundled payments. Employees are being asked to pay each time that they park rather than paying up front at monthly, quarterly, or yearly intervals. This change should encourage people to evaluate whether driving is the best option for them each day and could reduce the inertia associated with up-front payment.[65] We are also planning to study *incremental parking pricing*, an arrangement in which people have to pay more to park more, which may help break the driving habit.[66]

Research on loss aversion suggests that turning parking payments into a per-trip rather than a per-month amount could shift behavior so long as the fee is not perceived as negligible or does not round to zero. Concretely, organizations could ask their employees to pay for parking as a lump sum at the start of the year, with the understanding that rebates will be given at the end of the year for the amount not used. The employer could frame the approach in behaviorally informed ways, such as by emphasizing that, by not parking, employees can enjoy a "growing amount of rebate earned," or that, by parking, they "permanently lose a percentage of the parking cost for the year." This example illustrates the benefit of moving away from studying structural and behavioral interventions in isolation and applying behavioral insights to the design of fines and incentives.

In light of increasing income inequality and ongoing economic volatility, more research should focus on the efficacy of interventions that highlight the financial benefits of using commuting modes other than SOV commutes. Our initial studies and prior research suggest that messages that promote the cost savings of pro-environmental behavior are especially effective when people are worried about their finances.[47] Thus, people who are seeking financial independence or are concerned with their finances may be most motivated to change their mode of commuting if messaging about the new mode frames it as a financially beneficial activity, such as by emphasizing the cash saved on car insurance and parking.

Relatedly, behavioral interventions instituted to promote the use of public transport or carpooling will work only if people can realistically engage in an alternative commuting mode without incurring significant penalties in safety, convenience, or cost. Data from the studies described in Table 3 show that interventions were more effective when people lived near the public transportation routes advertised in our communications. Some strategies that cities could apply to reduce SOV commutes include introducing high-quality bicycle facilities and dedicated bus lanes, requiring major employers to submit a TDM plan and to track its progress, and creating and analyzing reduced-fare programs for low-income residents. (See references 67, 68, and 69 for recent examples of such programs.) Organizations and city governments could consider signing a joint public commitment to limit the number of business trips required of employees.

Future research could also explore other factors that prevent people from switching commuting modes, such as the perceived personal benefits of driving. People consistently report disliking car commutes, yet the "ideal" car commute length for most people is not zero.[70] In one study, people reported that their average desired commute length—regardless of mode—was 16 minutes.[70] Another study of over 400 car commuters found (after investigators controlled for the time variability caused by traffic congestion) that people with longer car commutes enjoyed them more.[71]

Such findings suggest that commuting by car can serve an important psychological function by providing uninterrupted time to plan the day and transition between personal and professional responsibilities. A potentially generative area of research would be to explore the psychological benefits of SOV commutes to better understand how alternative options might provide similar psychological rewards.[72,73] Another worthwhile effort would be to further examine the existence of—and ways to mitigate—*rebound effects*, in which people who drive less fly more because they feel that their relatively low daily carbon footprint gives them license to do so. A similar pattern has been found in relation to energy consumption; for instance, people who start taking public transportation often spend more on gas, heat, and electricity.[74]

"People consistently report disliking car commutes"

Research into the best way to increase the use of sustainable commuting modes would also benefit from the ability to easily collect smartphone, bus ridership, and parking data. When researchers measure objective behavior passively and continuously, their studies are less intrusive and easier to run, can more easily assess behavioral changes that unfold over time, and can avoid the reporting biases associated with self-reports. Lasting partnerships between researchers, employers, and owners of technologies that can readily collect ridership or parking data are needed to obtain these data and expand the scope of research on behavioral interventions.

As a result of our experiences establishing such partnerships, we believe that researchers should develop a proactive research agenda of foundational commuting questions up front and work toward these broad goals over time. Our ongoing interventions may have been more successful had we begun by outlining a specific set of research questions that we wanted to address (relating to the barriers we identified) instead of choosing to work with interested organizations to test the most feasible or convenient research questions available to us at the time. 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 require high-quality evaluation as a condition for funding. Existing foundation and government grant programs that are focused on environmental goals should also start to acknowledge the importance of behavioral science–related approaches in their ongoing work.

Our partnerships have revealed the interest of the TDM community in applying behavioral science principles to achieving shifts in the transport modes used by commuters as well as the challenges of conducting research in this area, such as the difficulty of accurate measurement. We hope this article will serve as a springboard for sustained collaborations between researchers and practitioners of TDM and provide a framework for encouraging these partnerships. Joint partnerships between academics, cities, TDM practitioners, and technology platforms will best enable the future design and implementation of effective behaviorally informed interventions.

author note

In the byline, we list the authors in reverse alphabetical order to reflect the collaborative nature of the research covered in this article while recognizing that Ashley Whillans took responsibility for writing and editing the article and addressing reviewer comments.

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