Effectiveness of Health and Environmental Information Provision in Promoting Sustainable Travel Modes

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ABSTRACT

Community-wide adoption of sustainable travel modes such as transit, walking, and biking can alleviate congestion and emissions while improving air quality and public health. However, promoting these modes in the U.S. is challenging due to the high reliance on personal vehicles, which contribute $260 billion annually in social costs. Information about health and environmental externalities of personal vehicle usage is often unavailable to travelers at the time of decision-making. This study explores whether mobile app-based information provision about the health and environmental benefits of sustainable modes can meaningfully change traveler preferences. In a sample of 3,470 U.S. car users aged 55 years and under, balanced by gender, income, and census regions, this study tested the effectiveness of information provision over a 90-day summer season, targeting bus transit, walking, and biking. Results show that participants who received information on environmental benefits related to emission reductions were four times more likely to choose bus transit, while those informed about active health benefits related to calories burned were nearly seven times more likely to choose walking, compared to the control group. However, due to barriers such as safety concerns and lack of infrastructure, health and environmental information was not effective at promoting biking. The results may be scalable to a large segment of travelers in the U.S., but the study did not test the effectiveness of these interventions for travelers 55 and over due to sampling limitations. Low-cost mobile app-based implementation strategies for possible deployment of these interventions in U.S. communities are discussed.

Keywords: Sustainable travel modes, mode choice, travel decision-making, information provision, health and environmental benefits

I. INTRODUCTION

The transportation sector in the U.S. is the largest contributor of greenhouse gas emissions, especially personal vehicle usage, accounting for 28% of total emissions (1). Travel-related air pollutants, such as NO_2 and $PM_{2.5}$, are associated with respiratory illnesses in adults and children, heart diseases and strokes, and adverse birth outcomes such as premature and low-weight births (2–4). These negative environmental and health externalities of personal vehicle usage impact individuals as well as their community, amounting to $260 billion in yearly social costs, including healthcare expenses and environmental damage (5). Community-wide adoption of sustainable travel modes such as transit, walking, and biking can offset these social costs by alleviating congestion and emissions, promoting active mobility, and improving air quality and public health. While some urban areas may have lower personal vehicle usage due to factors such as high parking costs, safety concerns, or congestion, census data (6) reveals a substantial reliance on personal vehicles among travelers. For instance, 82.27% of U.S. population depends on personal vehicles, while 53.71% in the New York metropolitan area and 80.43% in Metro Atlanta rely on personal vehicles. These figures underscore the significant dependance on personal vehicles. Despite the positive health and environmental impacts of sustainable modes, promoting them is challenging due to the high reliance on personal vehicles. Moreover, real-time trip-specific information about the immediate health and environmental benefits is seldom available to travelers at the time of decision-making, indicating a critical gap in information availability.

Information provision has been shown to be effective in inducing sustainable behavior in many decision contexts, including selection of healthy foods (7), energy conservation (8, 9), recycling and reuse (10), and waste reduction (11). For example, pro-social information provision about community benefits has been found to be effective in reducing energy consumption (8, 12–17) and pro-self information provision about health warnings on cigarette packages has been found to be effective in promoting public health (12, 18, 19). In the context of travel mode choice, preliminary studies have found that information provision related to the benefits of sustainable modes has high potential in demoting personal vehicle usage (20–22). However, these studies primarily relied on educating the participant about the health and environmental benefits of sustainable modes, rather than examining the impact of real-time trip-specific information provision. In promoting sustainable modes, the potential of real-time information provision about the associated health and environmental benefits is yet to be studied. Hence, this study examines the effectiveness of different health and environmental information in promoting sustainable modes.

Promising studies from public health literature show that benefits such as calories burned (23, 24), step counts (25), and heart health improvement (26, 27) are effective in promoting physical activity. However, they did not examine these benefits in the travel context. Air quality and carbon emissions have been investigated as effective environmental information in promoting sustainable modes (28–31), but real-time trip-specific information has not been examined for its impact on promoting these modes. This study examines the effectiveness of real-time information provision in promoting three sustainable modes: bus transit, walking, and biking. The information provision includes three types of health information (i.e., step counts, calories burned, and heart health) and two types of environmental information (air quality and emissions).

Traditionally, tolling and congestion pricing have been implemented to reduce private car usage (32, 33). However, public perception of these approaches is generally negative (33–35), further exacerbated by the inequitable nature of their impacts on disadvantaged groups, such as low-income travelers (37, 38). To overcome the issue of inequity, monetary incentives (e.g., reward points and cash) have been explored in various travel contexts, such as shifting to alternative travel routes, changing travel modes, and redistributing travel demand to reduce peak-hour congestion (35, 36, 39–44). While these monetary incentives are equitable, they are not sustainable in the long run because forming and maintaining sustainable travel habits requires continuous provision of cash incentives over time which is often impractical due to limited funding (43, 44). By contrast, given the widespread use of mobile devices, health and environmental information provision can be implemented in real-time through mobile apps at a significantly lower cost.

This study employs a stated preference survey design to test the effectiveness of different informational messages in promoting sustainable modes. The findings from this study can provide insights on which messages have higher potential in promoting sustainable modes, enabling policymakers to take the necessary steps to implement them in the real world. Low-cost strategies for possible implementation of these messages in communities across the U.S. using mobile apps is discussed. The rest of the paper is organized as follows: Section II illustrates the methods, Section III presents results, Section IV discusses the results and provides insights, and Section V provides concluding remarks.

II. METHODS

This study uses a stated preference survey design and was approved by Georgia Tech's Institutional Review Board (#H23240). The survey is randomized and includes several treatment groups to test the effectiveness of different health and environment related informational messages in promoting sustainable travel modes: bus transit, walking, and biking. The informational messages under five different categories were carefully crafted to convey the associated health and environmental benefits to individual traveler (pro-self), or their community (pro-social), or both (pro-self + pro-social) to promote sustainable modes. Each message highlights a health or environmental benefit and targets a specific sustainable mode. A series of small-scale surveys were conducted to improve the framing (in terms of context, language, and tone) of the messages. The following categories of informational messages were tested:

- Environmental – emissions
- Environmental – air quality
- Active health – step count
- Active health – calories burned
- Heart health

A. Informational messages using emissions

This set of messages highlights trip-specific emission reductions of each target mode compared to personal vehicle travel. Messages in **Table 1** communicate different scales of benefits (pro-self: benefit to individual travelers, pro-social: benefit to community, i.e., neighborhood) corresponding to the improvement in air quality resulting from emission reductions.

TABLE 1 Informational messages using emissions

Scale of benefit	Target mode	Informational message
Pro-self	Bus	"Take the bus to reduce 0.7 pounds of carbon emissions and improve the air you breathe"
Pro-social	Bus	"Take the bus to reduce 0.7 pounds of carbon emissions to improve the air in your neighborhood"
Pro-self and pro-social	Bus	"Take the bus to reduce 0.7 pounds of carbon emissions to improve the air you and your neighbors breathe"
Pro-self	Walk	"Walk to reduce 1.2 pounds of carbon emissions to improve the air you breathe"
Pro-social	Walk	"Walk to reduce 1.2 pounds of carbon emissions to improve the air in your neighborhood."
Pro-self and pro-social	Walk	"Walk to reduce 1.2 pounds of carbon emissions to improve the air you and your neighbors breathe"
Pro-self	Bike	"Bike to reduce 1.2 pounds of carbon emissions to improve the air you breathe"
Pro-social	Bike	"Bike to reduce 1.2 pounds of carbon emissions to improve the air in your neighborhood"
Pro-self and pro-social	Bike	"Bike to reduce 1.2 pounds of carbon emissions to improve the air you and your neighbors breathe"

B. Informational messages using air quality

Taking bus transit can reduce the exposure to air pollutants as buses undergo stringent maintenance, including regular air filter replacements, compared to personal vehicles where air filter maintenance is often neglected. Informational messages in **Table 2** are designed to illustrate the benefits of taking bus transit on air quality and the resultant reduced exposure to air pollutants. Three different messages are selected to differentiate the benefits to individual traveler, the community (e.g., neighborhood), and both.

TABLE 2 Informational messages using air quality

Scale of benefit	Target mode	Informational message
Pro-self	Bus	"Limit your exposure to air pollutants"
Pro-social	Bus	"Take the bus to reduce your neighborhood's exposure to air pollutants"
Pro-self and pro-social	Bus	"Take the bus to limit your and your neighborhood's exposure to air pollutants"

C. Informational messages using active health

Walking 10,000 steps a day is a popular health campaign that points to several health benefits, including improved blood pressure (45). Informational messages using daily steps can illustrate the progress of a traveler's daily step counts by adopting walking as a travel mode. Similarly, fitness tracking apps, such as Fitbit or Apple Health, are widely used to track calories burned during the day. Messages illustrating the calories burned by choosing walking or biking can communicate the impact of travel on active health. While maintaining an active lifestyle is beneficial to an individual traveler, it also positively benefits community health (46). **Table 3** shows eight messages designed to communicate the step counts and calories burned from walking and biking. While showcasing the calories burned, equivalent number of cookies are presented to make it more relatable.

TABLE 3 Informational messages using active health

Scale of benefit	Target mode	Informational message
Step counts		
Pro-self	Walk	"Complete 30% of your suggested daily steps"
Pro-social	Walk	"Walk to improve community health"
Pro-self and pro-social	Walk	"Walk to improve community health while completing 30% of suggested daily steps"
Calorie counts		
Pro-self	Walk	"You can burn up to 115 calories or 3 cookies"
Pro-self and pro-social	Walk	"Walk to improve community health while burning 115 calories or 3 cookies"
Pro-self	Bike	"You can burn up to 45 calories or 1 cookie"
Pro-social message	Bike	"Bike to improve community health"
Pro-self and pro-social	Bike	"Bike to improve your community health while burning 45 calories or 1 cookie"

D. Informational messages using heart health

Walking and biking are shown to reduce the risk of cardiovascular diseases (47). Individual heart health improvement collectively improves community health. Messages in **Table 4** are designed to convey these benefits to travelers.

TABLE 4 Informational messages using heart health

Scale of benefit	Target mode	Informational message
Pro-self	Walk	"Walk to improve your heart health"
Pro-self and pro-social	Walk	"Walk to improve your heart health and community health"
Pro-self	Bike	"Bike to improve your heart health"
Pro-self and pro-social	Bike	"Bike to improve your heart health and community health"

Survey Design

A stated preference survey design is employed to test the various informational messages. The survey takes 5-7 minutes to complete and consists of three parts as illustrated in **Figure 1**: (1) sociodemographic questions, (2) travel preference questions, and (3) scenario-based stated preference questions. The sociodemographic questions include age, gender, race, ethnicity, employment, education, and income. Travel preference questions include participants' usual travel time to work, their preferred travel modes for commute and non-commute trips, and a 7-point Likert scale question, ranging from 1 (strongly disagree) to 7 (strongly agree), with various statements (as outlined in **Table 5**, along with the intent of each statement) to gather data on opinions about health, environment, and willingness to choose alternative sustainable modes.

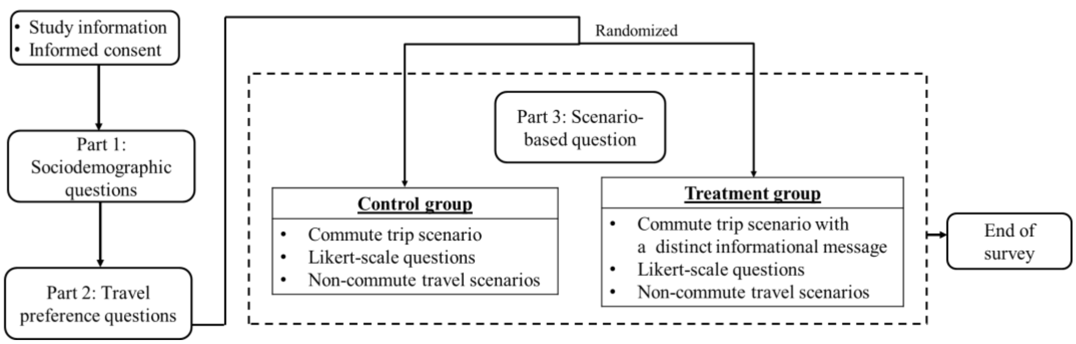
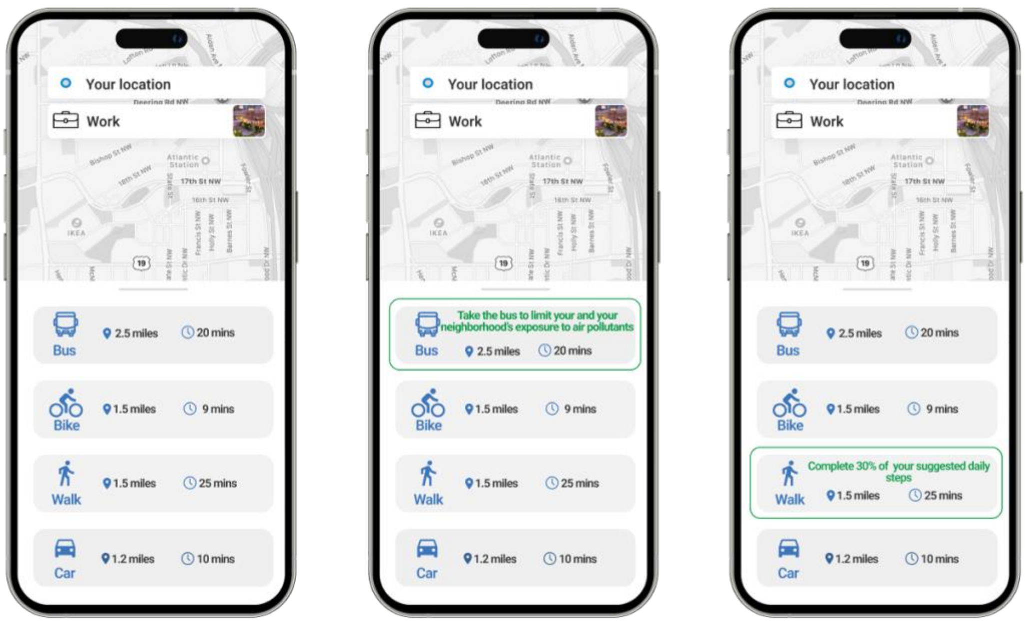


Figure 1 Survey flow

TABLE 5 Likert scale questions

Statement	Intent
I am open to trying out alternative modes (other than my preferred modes) for daily commute trips	Willingness to use alternative modes for commute trips
I am open to trying out alternative modes (other than my preferred modes) for daily non-commute trips	Willingness to use alternative modes for non-commute trips
I am concerned about my carbon footprint	Concern about carbon footprint
If I knew how to better reduce carbon footprint, I would take action	Willingness to take action to reduce carbon footprint
I maintain an active lifestyle	Level of physical activity
I am health conscious	Health consciousness
If I knew how to better contribute to improve air quality, I would take action	Willingness to take action to improve air quality

Scenario-based stated preference questions present participants with a hypothetical commute scenario, displaying a customized image of a mobile app featuring different travel options coupled with informational messages (a few examples are shown in **Figure 2**), mimicking a real-time travel decision-making. The survey is conducted as randomized control trials where, in the control group the scenario questions offer travel options with travel information, while each treatment group is presented with the scenario questions containing both travel information with a distinct informational message. Travel information, such as travel time and distance corresponding to each mode, remains the same across all treatment and control groups. The scenario-based questions are phrased as "Suppose you are on your way to work, and you use a navigation app (such as Google Maps, Apple Maps, Waze, etc.). You have four alternative options as shown in the screen below. Assume all four options are available to you. Please choose the option you prefer the most." As a follow-up to the scenario-based question, participants are asked to rate a few statements such as "I would change my behavior based on the message" on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Additionally, after the scenario-based question, participants are asked whether they would consider using the target mode for six different types of non-commute trips (i.e., shopping, entertainment, social, fitness, medical, and errands).



A. Control **B. Treatment examples**

Figure 2 Examples of images used in the scenario-based questions

Participant recruitment and sampling

Participants were recruited via the Prolific survey data collection platform based on the criteria that they are 18 years or older, live in the U.S., and are primarily car users. The participants were compensated based on the standard rates set by Prolific. An informed consent was presented to the participants at the beginning of the survey as shown in **Figure 1**.

III. RESULTS

A total of 3,470 participants completed the survey, balanced across gender, income, and census regions. The Prolific platform has very few individuals aged 55 and over. Hence, they were not included in this study. The participants were randomly assigned to one of the 25 groups (24 treatment and 1 control groups). A one-way ANOVA conducted on the sociodemographic variables revealed that there were no significant differences among the groups, indicating that the randomization was successful and the groups were comparable in terms of sociodemographic characteristics.

Overall, the participants rated positively across various Likert scale statements listed in **Table 5**. Specifically, 78.92% of the participants indicated that they are health conscious, and 71.85% indicated that they maintain an active lifestyle. Overall, 56.24% of participants expressed concern about their carbon footprint, and 60.43% indicated a willingness to take action to reduce it.

Impact of informational messages on willingness to choose sustainable travel modes

The willingness to choose sustainable travel modes in the presence of informational messages is recorded using a 7-point Likert scale, ranging from "Strongly disagree" to "Strongly agree". Since the response is on an ordinal scale, the effectiveness of the messages is analyzed using an ordinal logistic model (**Equation 1**). Each informational message's effect is compared against the control group.

$$Y_n = \alpha X_n + \epsilon_n \quad (1)$$

Here, Y_n represents a latent variable that determines the discrete ordered outcomes for each participant n, X_n denotes explanatory variables, e.g., sociodemographic characteristics, and α represents the coefficients. The odds ratios corresponding to the informational message are plotted in **Figure 3**.

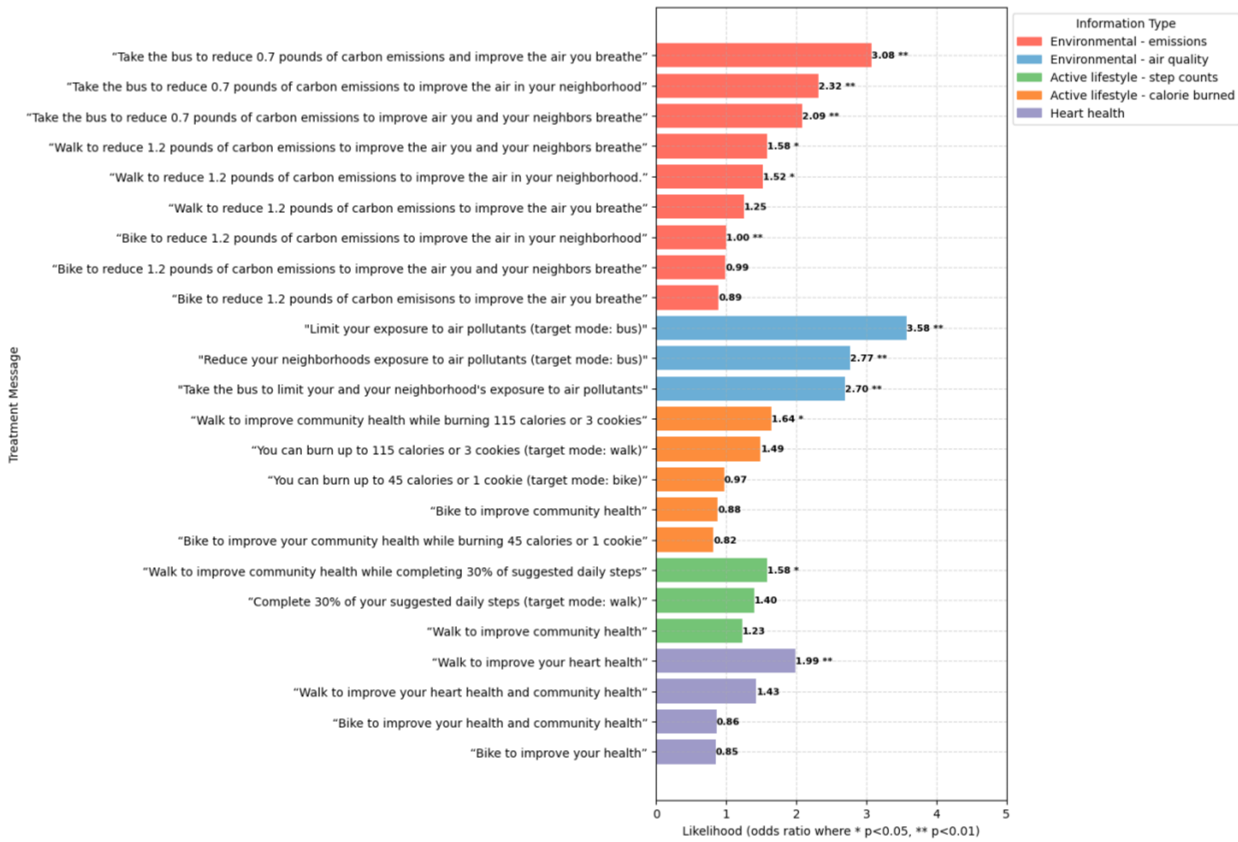


Figure 3 Effects on the willingness to choose sustainable modes in the presence of treatment messages compared to the control group (odds ratio)

Based on the ordinal logistic model, all messages with environmental information about emissions to promote bus transit are effective in increasing participants' willingness to choose bus transit. Of these, when the pro-self message was provided, the odds of willingness to choose bus transit increased by a factor of 3.08 compared to the control group. Pro-social message as well as combined (pro-self + pro-social) message with emissions information are also effective in increasing the willingness to choose walking. This could be attributed to the fact that 56.24% of participants expressed concern about their carbon footprint, and 60.43% indicated a willingness to take action to reduce it in the 7-point Likert scale statements.

All messages with environmental information about air quality are effective in increasing participants' willingness to choose bus transit. Of these, when the pro-self message was provided, the odds of willingness to choose bus increased by a factor of 3.58 compared to the control group. The air quality information likely aligns with their personal desire to reduce exposure to air pollution where 69.16% of the participants indicated a willingness to take action to improve air quality.

Messages highlighting calories burned while walking coupled with community health significantly increased the willingness to walk (odds ratio 1.64). Informational message about step counts (pro-self) coupled with community health benefits (pro-social) to promote walking significantly increased the willingness to walk (odds ratio 1.58). This could be because 71.85% of participants indicated that they maintain an active lifestyle. Step counts provide a clear and measurable personal health benefit making the message actionable. Additionally, community health benefits may appeal to individual's sense of social responsibility making it more likely to walk.

Pro-self heart health message significantly increased the participants' willingness to choose walking, with odds of choosing to walk increasing by a factor of 1.99 compared to the control group. This could be due to 78.92% of participants indicating that they were health conscious.

Impact of informational messages on travel mode choice

Since the responses to the scenario questions are categorical dependent variables, to understand the effectiveness of the informational messages on the mode choice, a multinomial logistic regression is used (**Equation 2**). Each informational message's effect is compared against the control group, with the baseline choice being the car (against which other mode choices are evaluated).

$$U_n = \beta X_n + \epsilon_n \tag{2}$$

Here, U_n represents the utility of participant n, X_n denotes the explanatory variables, β represents the corresponding coefficients, and ϵ_n is the error term. **Figure 4** shows the odds ratios corresponding to the informational messages.

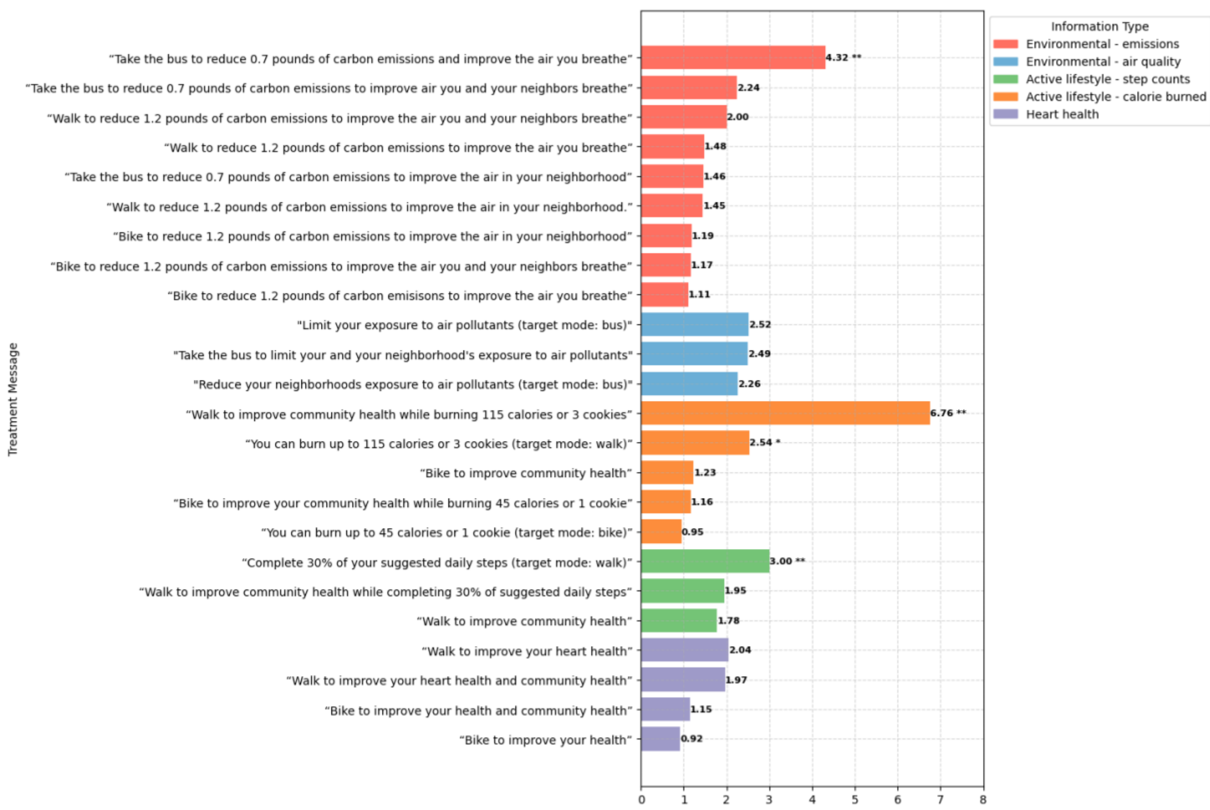


Figure 4 Likelihood of choosing sustainable modes in the presence of treatment messages compared to the control group (odds ratio)

The message that combined calories burned (pro-self) with community health (pro-social) was found to be effective in promoting walking. Considering that over 71% of participants agree that they maintain an active lifestyle, it is not surprising that the participants in this group were 6.76 times as likely to walk versus control group, especially for females (odds ratio of 10.77) and people with higher educational attainment (odds ratio of 4.20). Participants receiving a similar message highlighting only the calories burned from walking were 2.54 times as likely to walk versus control. Participants receiving pro-self information about step counts were 3.00 times as likely to walk.

Participants receiving pro-self environmental message using emissions information were 4.32 times as likely to choose bus compared to the control group. This could be attributed to 56.24% of participants expressing concern about their carbon footprint and 60.43% indicating a willingness to take action to reduce it.

Impact of informational messages on choosing sustainable travel modes for non-commute trips

In every treatment group, as a follow-up to the scenario question, the participants were asked whether they would choose sustainable modes for non-commute trips across six different non-commute trip types. A higher percentage of participants chose sustainable modes for fitness and social trips while medical trips had a lower percentage overall. For fitness trips, the activity itself (walking or biking) is aligned with the nature of the trip, making these modes naturally appealing. For instance, 61.43% of participants chose to walk for fitness trips when provided with a message illustrating the pro-self benefits in the form of step counts. Social trips, with their relaxed nature and potential social interaction, also observed higher percentages, with 60% for the same message. Entertainment trips also showed higher percentages of participants choosing sustainable modes for travel (for example, 46.43% of participants chose to walk with the same message). With entertainment trips (such as going to a concert), travelers could have difficulty in finding parking space leading to higher percentages of participants choosing sustainable modes.

By contrast, medical trips had a low percentage of participants choosing sustainable travel modes as they often require a high degree of convenience and reliability, which may be perceived as lacking in sustainable modes. They can also involve a sense of urgency which may prevent the consideration of sustainable modes with higher travel times. Next to medical trips, non-commute trips (errands and shopping) also had a lower percentage of participants choosing sustainable travel modes. Since trips pertaining to errands and shopping may have different requirements compared to commute trips, such as flexibility, carrying capacity, and convenience, lower percentages were observed. Overall, the informational messages promoting bus had a lower percentage of participants choosing it across all non-commute trip types. Non-commute trips often require multiple stops or travel during off-peak hours. Transit may be considered less convenient for these types of trips due to lower availability during off-peak hours and limited service areas.

IV. DISCUSSION

1. Informational messages with high potential to promote walking and bus transit

Information about environmental benefits highlighting emission reductions is found to be a strong contender to promote bus usage, which is consistent with prior literature (42). This message had a positive effect on both the scenario-based question and the willingness to choose question to promote bus usage. Calories burned along with community health benefits as well as step counts is a strong motivator to promote walking. This result is consistent with prior literature in medical and behavioral evidence domains (45, 46, 48, 49).

2. Divergence between stated willingness to change versus mode choice decision

Some divergence between participants' stated willingness to change and their mode choice in scenario-based questions is observed. While the information on the benefits of reduced carbon emissions increased the participants' willingness to choose bus transit, biking, and walking, they did not choose the targeted mode except in the case of messages promoting bus transit. This divergence may stem from their own perceptions about different travel modes as well as the practical challenges they face with biking and walking, despite their willingness to change.

Another source of divergence is evident in the impact of air quality information on bus transit adoption. While the information on the pro-social, pro-self, and combined benefits of air quality increased people's willingness to take bus transit compared to the control group, none of these messages led people to choose bus when presented with various travel modes in the scenario-based questions. This could be because, although the prospect of improved air quality is an appealing benefit of choosing bus transit over private vehicles, in practice, waiting for the bus may increase people's exposure to potential air pollution.

Information provision about heart health increased people's willingness to walk, but it did not lead them to actually choose walking in the scenario-based questions. This may be due to practical challenges such as distance, duration, weather, and other concerns.

3. Informational messages that were ineffective

Messages aimed at promoting biking had no impact on people's willingness to bike or their selection of biking in the scenario-based choices. Biking can be perceived as physically demanding and less convenient. Moreover, due to the lack of biking infrastructure in the U.S., biking can also induce safety concerns. So, even with the informational messages illustrating the positive benefits of biking, these barriers may outweigh the perceived benefits.

Overall, messages pertaining to heart health did not have any significant impacts in promoting walking and biking, and in case of the pro-self message promoting biking, a negative effect was observed. These mixed results could be because of differing perceptions of walking and biking. Walking may be perceived as more accessible and less strenuous while biking may be perceived as less convenient and physically demanding.

4. Low-cost mobile app-based implementation

Informational messages examined in this study can be easily implemented across communities in the U.S. with low cost and high efficiency. The widespread use of mobile phones makes the implementation cost-effective for large-scale implementation compared to the traditional monetary incentive-based approaches. Moreover, previous literature (42) illustrates the higher efficiency of information provision over monetary incentives. For example, the messages of giving up driving for environmental benefits received a 39% positive response, while monetary incentives had a 30% positive response (42).

V. CONCLUSIONS

This study explores whether providing mobile app-based information on the health and environmental benefits of sustainable travel modes can influence the preferences of personal vehicle users in the U.S. A stated preference survey is conducted as a randomized control trial to investigate the effectiveness of several health and environmental informational messages in promoting sustainable modes: bus transit, walking, and biking. The study finds that health and environmental information promote bus transit and walking, though the effectiveness varies across different modes and information. Information provision about pro-self environmental benefits (emission reductions) promotes bus transit effectively. Similarly, information provision about calories burned and community health benefits are effective in promoting walking. By contrast, information provision aimed at encouraging biking is not effective.

This study has two limitations. First, it conducted a survey to assess people's stated preferences by mimicking a real-time mode choice scenario by providing participants with images of a mobile app. However, field studies are needed to validate the effectiveness of real-time health and environmental information provision in promoting sustainable modes. Second, it did not test the effectiveness of information provision on travelers aged 55 and over due to the limitations of the Prolific survey platform which has few individuals in that age category.

The findings from this study highlight the importance of real-time health and environmental information provision in promoting sustainable modes, leading to real-world policy implications. For policymakers, designing and tailoring effective informational messages that highlight health and environmental benefits of sustainable travel modes is crucial for encouraging shifts from personal vehicle usage. Messages should highlight the individual benefits such as personal health and environmental impacts, as well as community health benefits. Specifically, messages promoting bus usage should incorporate information on emission reductions along with personal benefits, while messages promoting walking should prioritize information on calories burned and community health benefits. Additionally, low-cost implementation via mobile apps is scalable across the U.S., including small urban clusters and rural areas where funding is often limited. Further, to make these policies more effective in promoting biking, some supporting policies are needed to improve biking infrastructure and address specific situational factors such as safety, distance, and time constraints that may discourage travelers from choosing this mode.

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AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: Viswa Sri Rupa Anne, Omar I. Asensio, Gulam Kibria, Yifan Liu, Srinivas Peeta; data collection: Viswa Sri Rupa Anne; analysis and interpretation of results: Viswa Sri Rupa Anne, Yifan Liu, Gulam Kibria; draft manuscript preparation: Viswa Sri Rupa Anne, Gulam Kibria, Yifan Liu, Omar I. Asensio, Srinivas Peeta. All authors reviewed the results and approved the final version of the manuscript.

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