Trip Tracker: Investigating a tool for transportation mode choice to encourage people to reduce dependence on private car use through a more informed decision-making process.

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THESIS

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Introduction

Researchers have identified that, in the average American household, personal transportation is the greatest individual contributor of CO_2 emissions, responsible for 25% of air pollution, resulting in health and respiratory problems, and increasing the likelihood of climate change (Sorell, 2005). In order to limit these negative impacts of automobile use, many countries developed plans for the vehicle market from the early 90s (Azzi, 2011). Governmental bodies and transportation agencies have proposed a number of different strategies including changes in transportation policy, infrastructure, and technology (Sorell, 2005). Examples include developing a new roads system and increasing the energy efficiency of cars.

Besides technological solutions, the effectiveness of driver behavior on fuel consumption, eco-driving, has also recently become an important research theme (Azzi, 2011). Sivak and Schoettle (2012) used the term eco-driving in a broader sense including vehicle selection, maintenance, route selection and vehicle load. However, it generally refers to behaviors a driver can engage in while driving that reduce their vehicle's energy use and polluting emissions without compromising safety (Barkenbus, 2010). For example, eco-driving includes accelerating smoothly, avoiding sudden starts and stops, keeping an even speed, or minimizing braking. Therefore, a variety of on-board assistance system with feedback allowing drivers to monitor their driving habits so as to modify their current driving conditions has been developed and researched to provide help in eco-driving (e.g., Honda's Eco Assist and Ford's Eco Guide).

As many studies support the effectiveness of eco-driving feedback systems in terms of reducing fuel consumptions and emissions, they help control environmental problems (Kurani et al., 2015).

However, these solutions tend to be overshadowed by the continuing growth of car use (Steg & Gifford, 2005).

In the United States, there is over reliance on driving private vehicle (AASHTO, 2013). Recent research also support this by showing that half of all trips people take are only three miles or less, in other words, we drive almost everywhere we need to go, even to the closest destination (railstotrails, 2008). The problem is the predominance of the car has caused various direct and indirect issues not only on environment but also on economy and society (Gotschi & Mills, 2008). Although communities could benefit from more balanced transportation systems, substantially less attention has been placed on transportation mode choices. Therefore, reducing our dependence on cars and establishing balanced transport system is well worth exploring and promoting. Thus, I chose travel mode choice as the target behavior of my study.

This study focuses on investigating a tool for transportation mode choice to encourage people to reduce dependence on private car use through a more informed decision-making process. Here, I suggest non-motorized transportation modes: walking and biking, as alternatives to fuel powered vehicles. I have built a mobile application prototype, called Trip Tracker, which supports awareness of personal transportation choice, provides consequences of users choice in terms of various metrics (e.g., calories burned, co2 emissions, and fuel usage), builds landscape appreciation, as well as reinforces users commitment to change behavior through goal setting with friends.

Critiques of automobile dependency in this project do not mean that driving should be forbidden or shifted completely to alternatives. It simply suggests that, in a long term, reducing excessive car-dependency through substituting for short trips will establish a balanced transportation system that could generate to benefits to communities. Therefore, Trip Tracker mainly focuses on trips of three miles or less, which would be first step towards diverse transportation culture. In this thesis I hope to accomplish two main goals:

1) Design an intervention with the aim of controlling the excessive and unnecessary automobile usage and hence reduce the dependency on automobiles.
2) Field test the app to demonstrate its effectiveness in terms of behavior and attitudes.

In the next section, I describe an overview of the current trend of automobile dependency and issues caused by this trend.

Automobile Dependency

Litman (1999) defined automobile dependency as high levels of per capita automobile travel, automobile oriented land use patterns, and reduced transport alternatives. In United States, automobiles have dominated our surface transportation system since 1956 and the birth of the Interstate Highway System. Federal funding has excessively focused on accommodating cars and trucks. The number of vehicle miles traveled by passenger cars and light-duty trucks increased 35% from 1990 to 2012 (EPA, 2014). According to the 2001 National Household Travel Survey, 48 percent of all trips were three miles or less and 24 percent were one mile or less. This means people might consider that driving is the only option for traveling even to the closest destination. Rates of car ownership in the United States are the highest in the world, and the number of cars per household now exceeds the number of drivers. (Gotschi & Mills, 2008) In 1990, the average number of passenger kilometres travelled by private car in the US (18,650 km) was more than double the Western–European figure (Steg&Gilfford, 2005). These high levels of per capita automobile travel, automobile oriented land use patterns, and lack of transport alternatives have caused various direct and indirect issues on the economy, environment, and society.

The first problem caused by over-reliance on automobiles is the inevitable consumption of non-renewable resources. Americas' private cars and trucks burn 40% of the oil consumed in the United States, equivalent to 10 percent of world demand (Gotschi & Mills, 2008). Considering the fact that the United States makes up 5% of the world population, it is a huge amount of fossil fuel usage (Oil Use and Fuel Consumption, 2014).

Moreover, greenhouse gases emitted by fossil fuel-based motor vehicles threaten people around the globe. The concentration of greenhouse gases causes global warming which shows its effects across the world in forms of rising sea levels, droughts, floods, typhoons and so on. Most of these emissions come from human activities, and transportation has been the largest emitter among end-use sectors (U.S. Carbon Dioxide Emissions from Energy Sources, 2009). In 2012, automobiles were responsible for about 28 percent of the total United States' CO_2 emissions and the fastest growing major source of greenhouse gases (Greenhouse gas emissions from the U.S. transportation sector, 2006). More specifically, one gallon of gas burned produces 19.4 pounds of carbon dioxide (CO_2), nearly a pound per mile driven (Gotschi, & Mills, 2008)

Automobile dependency causes not only environmental problems but also negative social impacts. Peter Newman (1996) stressed that automobile oriented city transport systems and spatial structures cause equity issues. For example, low-income households earning less than $ 20,000 annually spend at least 28% of their income on transportation, whereas higher-income households earning more than $50,000 annually only spend 18% of their income on transportation, due to lack of an efficient public transit system. This statistic indicates that automobile dependency is a financial burden to the poor. Also, people living in peripheral areas spend three or four hours per day commuting to and from work because of congested roads and inefficient transit system. Therefore, those who cannot drive or cannot afford personal vehicles become increasingly disadvantaged, as city transport systems and spatial structures become increasingly automobile oriented. Moreover, non-motorists are also forced to bear the social and environmental costs that motorists directly or indirectly generate. (Neman, P., 1996).

Car oriented transport culture also produces physical separation between people and reduces opportunities for social interaction. When driving was not major, there were more opportunities for interaction among individuals through easy foot access. However, when everyone is in cars there can be no social contact between neighbors, and social contact is essential to developing commitment to neighborhood (Litman, T.,1999). This social stratification impedes the development of a socially vibrant community (Litman, T. 1999). According to Donald Appleyard, as traffic volumes increase, quality of life factors that lead to healthy and strong communities such as social connections and neighborhood pride decrease (Appleyard, D., 1981).

Lastly, auto-dependent development caused aesthetic degradation of landscape. Landscape beauty and cultural resources such as historic structures and sites are threatened by large roadway and parking facilities. Automobile oriented urban area uses a large landscape for parking facilities and stores put competitively raucous signboard to catch drivers' attention. Therefore, attractive and healthy landscapes have disappeared. This will worsen the automobile dependency since aesthetic quality of landscapes is positively related to increasing the propensity for walking and bicycling (Litman, T.,1999).

Although a certain amount of automobile travel is efficient and productive, considering the above-mentioned negative consequences of car use, we need diverse transport system, which allows viable transport choices and incentives to use each mode for what it does best (Litman, T.,1999).

Co-benefits of non-motorized alternatives

Many people consider cars are better than other modes in terms of travel time, flexibility and comfort. However, non-motorized alternatives such as cycling and walking substantially benefit to individual and society. Gotschi and Mills (2008) argue that 2.4 to 5 billion gallons of fuel would be saved from shifting short trips to bicycling or walking. This is equivalent to saving 21 to 45 million tons of CO_2 a year. According to their scenario, a bicycle commuter who rides five miles to work, four days a week, saves 100 gallons of gasoline and 2,000 pounds of CO_2 emissions for a year (Gotschi & Mills, 2008).

Furthermore, less automobile oriented communities will improve public health. According to a report published by the Institute for European Environmental Policy (IEEP), people can save 15.4% of total emissions from passenger cars equivalent to 11 $MtCO_2$ and avoid an average weight gain of 2lb 11oz each year by returning to the walking patterns of 30 years ago. The walking patterns of 30 years ago when car ownership was less common can be achieved by walking just 1 hour more during the week (Davis, Valsecchi, & Fergusson, 2007). Another study also argues that shifting one-third of short trips from driving to bicycling would reduce 5-10% of heart disease (Bike For Your Life, 1995). Since sedentary lifestyle has the cardiovascular risk equal to smoking 20 cigarettes a day, encouraging non-motorized transportation could be a practical way to obtain exercise (Litman, T.,1999).

Moreover, improvements of walking and cycling conditions can provide user enjoyment benefits similar to those provided by public parks and trails. Considering communities typically spend more than a hundred dollars annually per capita on facilities such as parks and sport centers, it is significant value. In many areas, pedestrian and bicycle friendly environments are major tourist attractions. For example, San Antonio's Riverwalk in Texas and Venice, Italy provides adequate safe and enjoyable walking and cycling conditions (Litman, T.,1999).

Given the evidence for the relationship between automobile usage and urban resilience, changing travel behavior merits further investigation. Our community would be more resilient if people drive less, therefore, consuming less oil, emitting less pollution and conserving landscape environment.

Behavioral Theory

Some studies have shown that improved facilities for non-motorized transport modes such as bicycling can lead to an increase in use. A review of 14 case study cities by Pucher, Dill and Handy (2010) shows that almost all cities adopting comprehensive packages of interventions including infrastructure provision and pro-bicycle programs, supportive land use planning, and restrictions on car use experienced large increases in the number of bicycle trips and share of people bicycling (Pucher, J., Dill, J., & Handy, S., 2010).

On the other hand, many researchers suggest that while improved external infrastructure such as cycling facilities can make cycling safer they do not necessarily lead to behavior change, in this case, more cycling (Gatersleben & Appleton, 2007). For example, the National Cycle Strategy introduced by UK government in 1996 aimed to double the number of cycling trips by the end of 2002 and double them again by 2012. Their strategy included developing convenient cycle access, providing cycle parking at all major destination, and improving cycle safety. However, the targets unfortunately have not been met. This failure may have been caused by a fundamental lack of commitment to cycling on an individual level (Gatersleben & Appleton, 2007). Also, in psychological perspective, this is related to “mental shortcuts” which means people use to make judgments quickly based on the ease with which they can bring something to mind. Once people made their choice, they prefer to be consistent with their choice they have made before (Aronson et. al. 2010).

Therefore, it is important to think beyond the role of physical and built environment factors when attempting to understand transportation mode choices. A plethora of research in this area focuses on individual's internal decision-making process based on attitude models. A commonly used model is the theory of planned behavior (TPB; Ajzen, 1991). This model suggests that three kinds of considerations: attitudes towards that behavior, perceived subjective norms (what others think and do) and perceptions of behavioral control which means beliefs whether the behavior is easy or difficult to do, in order to influence on intentions to change behavior. According to this model, providing the right kind of information will allow people to make more informed choices. That is because the theory assumes that behavior is reasoned, controlled, or planned (Gatersleben, B. 2012). There is plenty of evidence that the components of the TPB accurately predict intentions and actual behavior. Bamberg, Azen and Schimidt (2003), for instance, designed an intervention to increase the number of students who ride the bus rather than drive their cars. They provided prepaid bus tickets to students. They found that introduction of prepaid semester bus ticket raised attitudes, subjective norms, and perceptions of behavioral control, thus strengthening intentions to do so and ultimately affecting reported behavior (Bamberg, Azen, Schmidt, 2003).

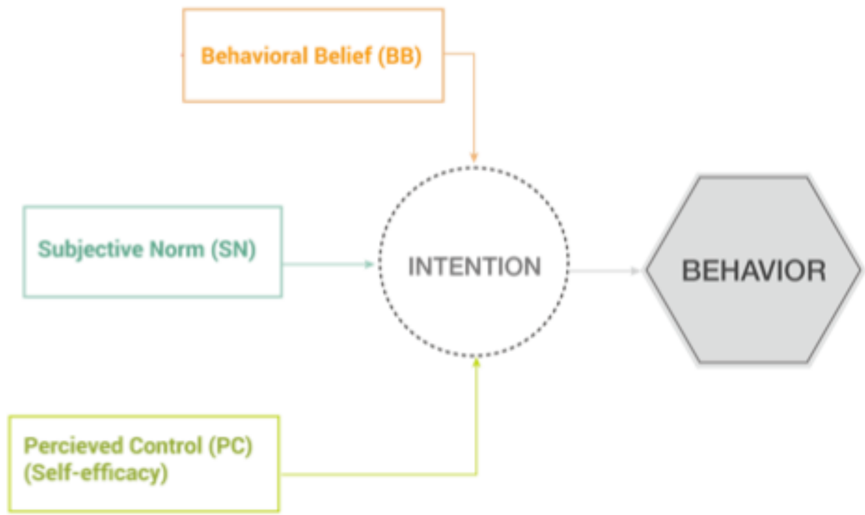

FIGURE 1 Theory of Planned Behavior (TPB; Ajzen, 1991)

TPB has been challenged by the argument that human behavior is habitual or automatic (Verplanken and Aarts, 1999 in Bamberg, Rolle and Weber, 2003). Gatersleben (2012) argues that travel mode decision is not a planned behavior but a habit, thus, it takes place without much thinking or conscious planning (Gatersleben, B. 2012). However, Bamberg, Rolle and Weber (2003) provide empirical evidence that past behavior (past car use) and habit does not effect on future travel mode choice. The results show that even in the case of a behavior has become routine, people may change their intentions and behaviors based on new information perceived as personally relevant and persuasive. In their study, they provided a free ticket valid one day for all transport services with a map, timetable and other useful information for using public transportation services (Bamberg, S., Rölle, D., & Weber, C., 2003). They also note a “sensible phase” (p. 105): a new decision context in which people’s attention to new information and their motivation to process it more actively is increased. ‘Habit discontinuity hypothesis’ also supports that people in a new decision context, for example, when they have moved home or job, are likely to re-evaluate important values and change behavior (Verplanken et al., 2008 in Gatersleben, B. 2012). If this hypothesis is correct, it would have important implications for attempts to change routine behaviors. For example, if we attempt to introduce new behavior change regarding to recycling, it would be much effective to target people who just changed the place of residence.

Transportation mode decisions have often been defined as social dilemma by many researchers Social dilemma denotes a conflict between (short term) individual interests and (long term) collective interests which sometimes require sacrificing immediate individual gains. Many studies have revealed that some people tend to evaluate choices in social dilemmas in terms of moral obligation (Nordlund, A. M., & Garvill, J., 2003). Thus, the majority of studies employing TPB in the context of pro-social and pro-environmental behavior have tried to incorporate the Norm Activation Model (NAM; Schwartz, 1977) in order to enhance the predictive ability of the standard TPB constructs (Stern, 2000; Onwezen et al, 2013). Schwartz (1977) developed the NAM explains that individual behavior predictor is personal norms, in other words, moral obligation. Awareness of behavioral consequences and the feeling of responsibility for performing the behavior determine the personal norms.

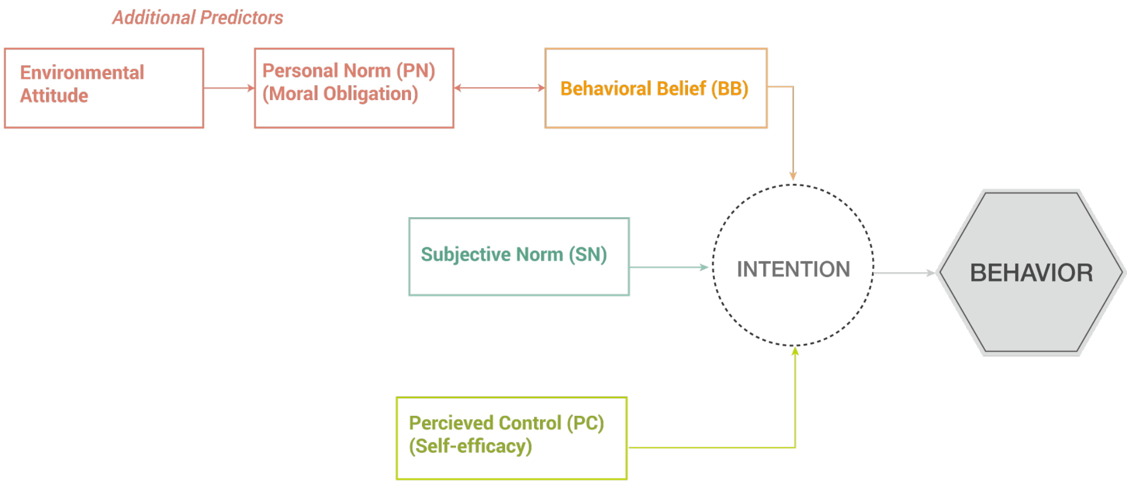

FIGURE 2 Behavioral Model 2 (Personal Norm and Environmental attitude included as an additional predictor to TPB)

In addition, Nordlund and Garvill proposed that the individual's **environmental value orientation** is important for establishing or increasing a general awareness of environmental problems, which will be a basis of the personal norm (Nordlund & Garvill, 2003). Several theories have categorized environmental value in various ways but they used a scale constructed by Thompson and Barton (1994). They divided environmental values into two categories: ecocentrism and anthropocentrism. Ecocentrism represents the belief that the ecosystem has an intrinsic value and this alone is a reason for protecting it. Anthropocentrism represents the belief that the environment should be protected because of its contribution to human welfare. The result of this study indicate that people closer to ecocentrism are more likely to feel morally obligated to cooperate for pro-environmental behavior. Therefore, in order to increase the willingness to reduce personal car use, ecocentric values and negative environmental consequences of car use should be emphasized thereby accentuate the moral dilemma of personal car use.

Another concept concerning individual environmental values is termed the connection to nature (Kaplan, 2000) or inclusion of nature in self. (Schultz,) According to Kaplan (2000), increasing the connection to the natural environment may be more effective than establishing laws and rules in order to motivate ecological behavior.

In conclusion, improving facilities and infrastructure may not be enough to influence personal transportation mode choices. Strategies rooted in an understanding of behavioral processes related to travel mode choice are necessary. TPB is a popular model of behavior change, but has limitations with regard to habitual and complex behaviors like travel mode decisions. Other useful constructs include personal norms, moral obligation, and thus, we should consider other variables such as personal norm since travel mode decision has been considered as social dilemma. Also, as many authors proposed, environmental attitudes are positively related to personal norm, which derives people's willingness to reduce car.

Preliminary Survey

The preliminary survey constructed using the model of TPB (Ajzen, 1991) was conducted to collect following information: 1) Demographic information, 2) Behavioral predictors includes: a) current intention to drive less, b) current expectancies of their choice, c) how they feel attached to car, d) normative beliefs of alternative modes, specifically bike, 3) Personal norm. This survey is intended to test the applicability of the combinations of theoretical constructs to the specific context of my study (travel mode choice for short trips). Moreover, the survey is for understanding what kinds of behavioral variables need to be supported in order to increase intention thereby to identify the most effective solutions in a variety of situations.

The preliminary survey data were collected between December 9, 2014 to January 12, 2015. The participants were recruited via campus email. In order to minimize the impact of external variables such as infrastructure for alternative modes or weather conditions, people live in Davis, California were recruited. 86 people completed and returned the survey. However, the questionnaires returned by the respondents were found to contain missing data. To avoid contamination by careless responding, and for ease of analysis, listwise deletion of missing data were employed. In addition, participants were excluded if they indicated in the survey they have any temporary or permanent physical conditions that limit their ability to walk, bike, or drive. These procedures resulted in reduced sample sizes that ranged from 86 to 69. Participants in this survey sample were 43.48% male 56.52% female and ranged in age from 18 to 77 years, with a mean of 30 years.

The travel mode alternatives to driving considered in this research were bicycling and walking. Respondents answered questions designed to measure each of the predictors in TPB: behavioral belief (expectancies), subjective norm, perceived behavioral control, and intention. In addition to assessing the predictors in the theory of planned behavior, a question inquired into the respondents' moral responsibility to use the car less was also provided.

Expectancies of alternative mode use were assessed by means of the following three items: (a) "How much do you agree or disagree with shifting your car use to cycling or walking will reduce environmental impacts? ", (b) "How much do you agree or disagree with shifting your car use to cycling or walking is good value for your money?" and (c) "How much do you agree or disagree with shifting your car use to cycling or walking benefits health and fitness?" The two subjective norm items were formulated as follows: (a) "How often do the members of your household bike?" and (b) "My friends generally perceive that cycling for transportation is cool." To assess perceived behavioral control, respondents answered the item of the following form: "Please rater your level of inconvenience if you could no longer drive.(Rank your answer on a scale of 1: Not at all to 5: Very inconvenient)." Participants also responded to the following intention item: "Would you be willing to commit to walking or cycling to all destinations that are less than three miles? " For moral responsibility, they answered the item of the following form: "Are you trying to use the car less for environmental reasons?"

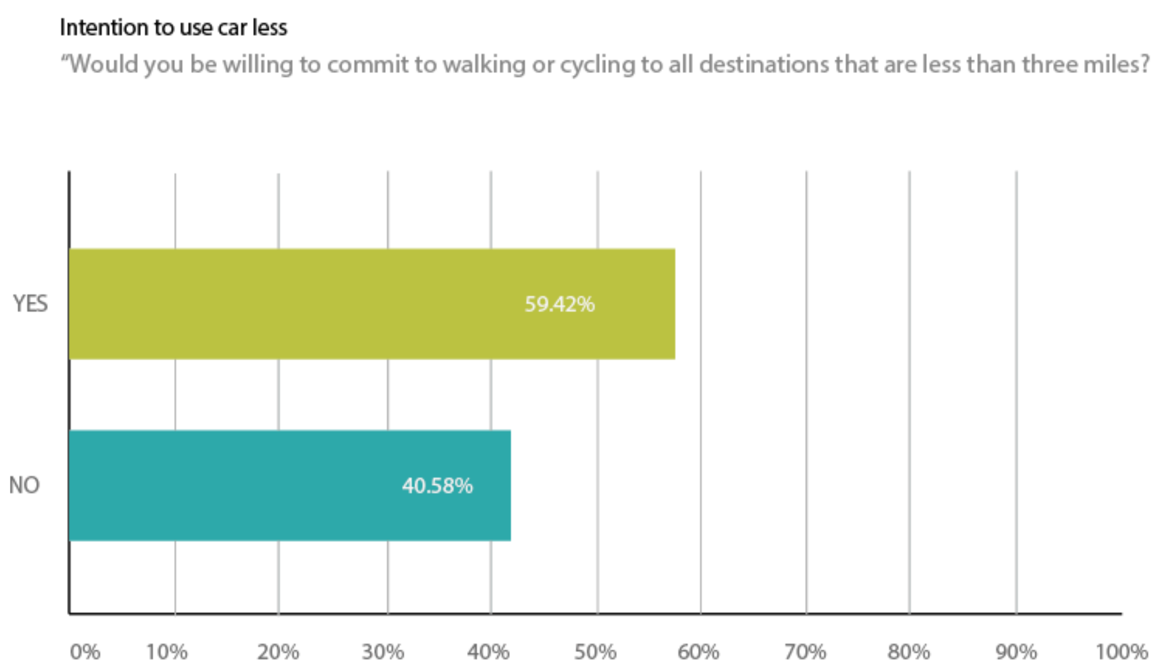

FIGURE 3

As a result, 59.42% of total participants are willing to commit to use alternatives to the car in future whereas 40.58% are not willing to make the commitment for changing behavior (Figure 3).

Inferential statistical tests were run on the survey data. Specifically, t-tests and chi-square tests, as appropriate given the data structure, were used to determine if participants who reported willingness to curtail car use (behavioral intention) differed from those who were not willing to make this commitment in their responses to items measuring behavioral beliefs, control beliefs, and social norms.

Similarly, tests were run to determine whether participants who reported trying to use their car less for environmental reasons (moral responsibility) differed from those who were not making this effort in terms of their behavioral beliefs.

Two significant findings emerged from these analyses. First, participants who reported a willingness to commit to walking or cycling to destinations within three miles distance (behavioral intention) rated their level inconvenience if they could no longer drive (control belief) as significantly lower than participants who were not willing to commit to walking or cycling to destinations within three miles distance, $t(69) = -4.22$, $p < .001$. Second, participants who reported trying to use their car less for environmental reasons (moral responsibility) were significantly more likely to also report belief in the statement that shifting car use to cycling or walking will reduce environmental impact compared to participants who were not trying to reduce their car use for environmental reasons (behavioral belief), $t(68) = 2.80$, $p = .007$. Other behavioral predictors such as behavioral belief subjective norm also show expected patterns (a positive relationship with intention). However, they did not reach statistical significance in the test. Therefore, further study should verify this with larger sample size.

To summarize, stronger intentions to use an alternative mode are related to: less psychological attachment to the car and stronger moral responsibility. Therefore, we can conclude that emphasizing self-efficacy (control belief) towards the behavior and moral responsibility will impact on people's attitudes and behavior. Next chapter describes the design development and evaluation of Trip Tracker.

Design development

Trip Tracker

Based on the results of the formative research, I designed Trip Tracker, a smart phone application that helps to motivate people to reduce dependence on private car use through a more informed decision-making process. The reason I choose a smart phone application as a platform because it has considered as the most useful platform for changing human behavior. B.J. Fogg (2007) explains the three major reasons why mobile phone is the most useful platform for persuasion: (1) a mobile phone is extremely private which means that people spend more time with mobile phones than with their family; (2) people carry their mobile phone almost everywhere they go; (3) a mobile phone can realize a lot of function (Fogg, B., Eckles, D., 2007). Moreover, due to the connectivity technology, publishing on the mobile web is the quickest way to reach a global audience.

Trip Tracker is employed strategies partially based on findings from theory of planned behavior (TPB) and Norm Activation Model (NAM). The behavior change strategies include:

1) Increasing awareness of behavioral consequences.
2) Building environmental appreciation through sharing of beautiful routes
3) Creating social influence to change behavior
4) Setting a goal to motivate behavior

First, third and fourth strategies relate to strengthen behavioral belief, social norms and perceived control (self-efficacy) that are important psychological factors for formulating intention according to TPB. Second strategy is focus on increasing eco-centric interests that can strengthen moral responsibility. This strategy helps emphasizing the intrinsic rewards of being in natural settings through experience in nature.

1. Strengthen awareness of behavioral consequences

FIGURE 4 Calendar

The first screen of Trip Tracker shows a calendar illustrates the pattern of transport mode choices with color codes. Three main colors represent each mode: by vehicle, by foot, and by bike. On the calendar, the colors blend based on the types of modes the user took and number of trips of it. The ratio of color blending is not based on the distance of trips but based on the number of trips since this project is for increasing frequency of alternative mode use. There is also a button on the top right that can switch showing results of all trips and local trips. Local trips mean trips less than 3 miles. This will prevent discouraging people who have to take unavoidable long distance work commute for long distance. Overall, this self-monitoring function also allows people to see themselves so as to modify their behavior to achieve their goal.

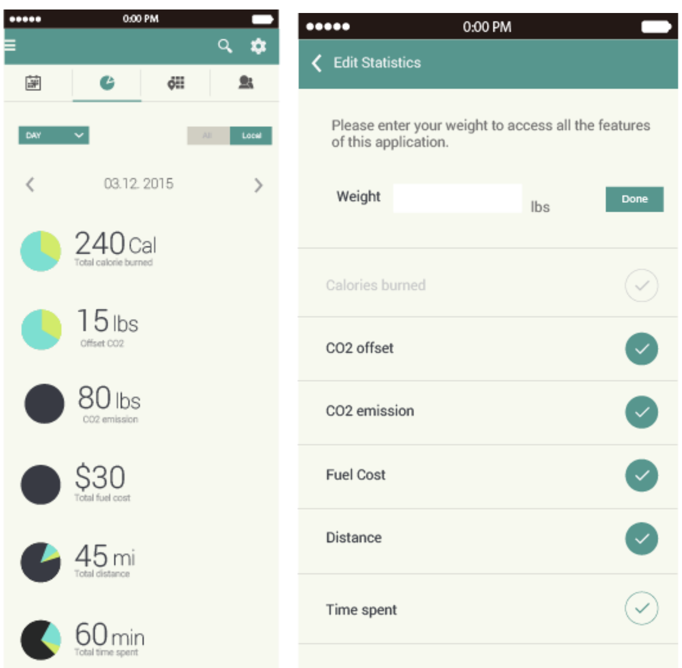

FIGURE 5 Statistics and Edit Statistics

In the statistic screen, it shows the analysis of costs and benefits. A list of statistics including calories burned, Co2 offset, co2 emissions, fuel cost, distance and time spent. Various statistics have intention to appeal to different motivations such as fitness, financial, social, and time management. I also attempt to communicate numerical statistics in a more meaningful way through creating an emotional connection between the individual and the environmental consequences of transportation mode decisions. It will help users to develop a picture of how many of my short-term decisions have long-term impacts.

Calories consumed by use of each modes walking, biking and driving will appear under "Calories burned". The amount of CO2 emission saved by biking and walking instead of driving will be shown under "CO2 offset". These two categories work as a rewards for use of alternative modes. On the other hand, "Co2 emission" and "Fuel usage" are directly related to driving. Thus, these two categories are for emphasizing negative impacts of car use. Distance and Time shows accumulated information of all transportation modes. Moreover, this statistics are mixed with human centered values (e.g. calories, cost and time) and biosphere values (e.g., co2 emissions and co2 offset) in order to appeal different motivations. There is a function that users can select the statistics and their units that they think interesting and persuasive in "Edit Statistic".

FIGURE 6 Additional units for each metrics

As Table 2 illustrates each statistic except distance and time provides one most commonly used unit and two additional choices of different units. Therefore, users can choose the unit that is less salient to them in the edit screen. The reason Trip Tracker providing a choice of different units is because those are considerably easier to picture the costs of their action oppose to calories, pounds, and gallons. Details about each unit will be discussed later. The graph that is right side of the numbers shows the percentage of each mode contributes to the statistic with colors. Users will be able to understand the true cost of their actions and choices. Moreover, the cognitive representations of alternatives will be established in users mind through repeatedly presenting a positive consequences such as getting exercise, saving trees, etc. that the user may care. For the future research, the data of user's unit choice will be a base for developing a methodology for designing different feedback strategies tailored to different demographical or psychological background of people.

Trip Tracker Equations

Calories burned

Trip Tracker uses Dr. Bill Haskell's Compendium of Physical Activities(CPA) tables to calculate the calorie burn for different activities. The Compendium has been used in various studies for developing innovative ways to assess energy expenditure in physical activity (Ainsworth et. al, 2011). Table 3 shows CPA tables of activities that I used for calculating calories burned.

Activities	METs	Transferred MET unit to lbs
Walking for transportation, 2.8-3.2 mph, moderate pace, firm surface	3.5	1.587
Bicycling, to/from walk, self selected pace	6.8	3.08
Riding in a car	1.3	0.59
Jogging, general	7.0	3.17

The following equations (1) to (4) are used for calculating the calories burned by each mode.

(1) Calories burned by foot = 1.587 × User's Weight(lbs) + walking time(min) ÷ 60

(2) Calories burned by bike = 3.08 × User's Weight(lbs) + biking time(min) ÷ 60

(3) Calories burned by vehicle = 0.59 × User's Weight(lbs) + driving time(min) ÷ 60

(4) Total Calories Burned (Cal) = (1) + (2) + (3)

Although an individual's physique and environmental variables may cause significant differences in calorie consumption, the algorithm used for calorie counting in this app is based on general population averages. Thus, the data may not accurate for every individual in various circumstances. However, in order to get the accurate data, users should input a lot of their personal data in the app, which might cause low usability. The core concept of Trip Tracker is automatic tracking and analyzing transportation activities. Therefore, the first version of the app focuses on making complex task simpler and easier. However, it may ask people to input their information such as gender for more accurate feedback in later version if there are users' needs. Because people can easily sync calories with food and exercise, "tablespoons of butter" and "minutes of jogging" are provided for users as choices of unit.

$$Tbsp\ of\ butter\ = \frac{Total\ Calories\ Burned(Cal)}{102}$$

$$\text{Min of jogging} = \frac{Total\ Calories\ Burned(Cal)}{\text{user's weight} \times 3.17} \times 60$$

CO2 sequestered

CO2 offset refers that CO2 emissions saved by biking and walking instead of driving. As a default setting, it provides commonly used units of CO2 that is pound. According to EPA, 1 gallons of gas emitted 19.4 pounds of CO2. For my calculations, I used the common conversion of the approximation of fuel usage in average city driving: 25 miles per gallon.

$$\text{CO2 sequestered (lbs)} = 19.4 \times \frac{biking{+}walking\ distance}{25}$$

However, for some people, converting carbon dioxide into weight (pound) is abstract. For example, it is difficult to picture what 10 pounds of CO2 really looks like. So we need more direct and sensory ways of translating the abstract measurements into concrete terms that we all can understand. Thus, Trip Tracker also provides other choices of unit such as (1) the estimated number of trees that offset same amount of co2 saved by biking and walking, and (2) carbon credit the user have been saved. According to Crandell (2007), One evergreen tree absorbs approximately 85 pounds of carbon dioxide (Crandell, 2007). This estimate assumes that the tree is planted in an urban setting and allowed to grow for 10 years. This approach will quantify a conceptual idea, biking and walking are environmental friendly behavior. Moreover, the positive reinforcement will encourage people to change their mode choices.

$$\text{Adult (10 years) evergreen trees} = \frac{Co2\ sequestered\ (lbs)}{85}$$

Another approach to make CO2 that is invisible to tangible is converting it into carbon credit. A carbon credit is a certificate representing the reduction of one metric ton (2,205 lbs) of carbon dioxide emissions. Therefore, every ton of emissions reduced results in the creation of one carbon credit. In the same manner, we can offset our CO2 emission through purchasing credits that fund the destruction of CO2. There are many ‘brands’ of carbon credits. Trip Tracker uses “Terrapass” which is one of the popular ‘brands’ of carbon credits for converting CO2 into cash. Terrapass currently set a price for 1,000 lbs of CO2 as $5.95. Thus, the equation is:

$$\text{Carbon Credit (\$)} = \frac{CO2\ sequestered\ (lbs)}{1000} \times 5.95$$

Co2 emission

CO2 emission illustrates the amount of CO2 emitted by driving. As same as CO2 offset, it uses EPA's calculation for CO2 emission per gallon of gasoline, and the common conversion of the approximation of fuel usage in average city driving: 25 mpg.

$$\text{Co2 offset (lbs)} = 19.4 \times \frac{Driving\ distance}{25}$$

However, many people don't have a direct comparable sense of how much and serious the amount of CO2 is. Therefore, Trip Tracker compares the amount of CO2 emitted by a user with other CO2 emitter. The comparison in the first version of Trip Tracker is volcano.
Werner and her colleagues of Penn State found that Yellowstone's Mud Volcano area produced about 176,300 tons of carbon dioxide each year (Yellowstone Park Emits Tons of Carbon Dioxide, Study Finds. 1997). Thus, Yellowstone's Mud Volcano emits 11 lbs of CO2 in one second. The calculation for carbon credit is same as CO2 savings.

Co2 emissions (lbs) / 11 = sec

Fuel Usage

For fuel usage, I used the common conversion of the approximation of fuel usage in average city driving: 25 miles per gallon. I also want users to know what was required to generate fossil fuels. Therefore, users can picture the true cost of their usage and elicit emotional response. Oil is made of plants and animals buried millions of years ago. Those prehistoric, buried plants and animals converted by pressure, heat and time into oil. So, I add "tons of dinosaur" in a gallon of gasoline as an additional unit. According to a study conducted at the University of Utah, 98 tons of prehistoric material needed to produce each gallon of gasoline we used for vehicles (Dukes, J. S., 2003) Thus, the equation is:

driving distance / 25 = Fuel usage (gal)

Fuel usage (gal) X 98 = ancient plants & animals (ton)

People normally charge their gas weekly or monthly. So, it is hard to know how much they spend for a specific trip. Therefore, perceived cost of driving and actual cost might be different. Based on current fuel cost, Trip Tracker calculates how much user spent on the specific trip.

Fuel usage (gal) X 3.70 = $

2. Building Environment and landscape Appreciation

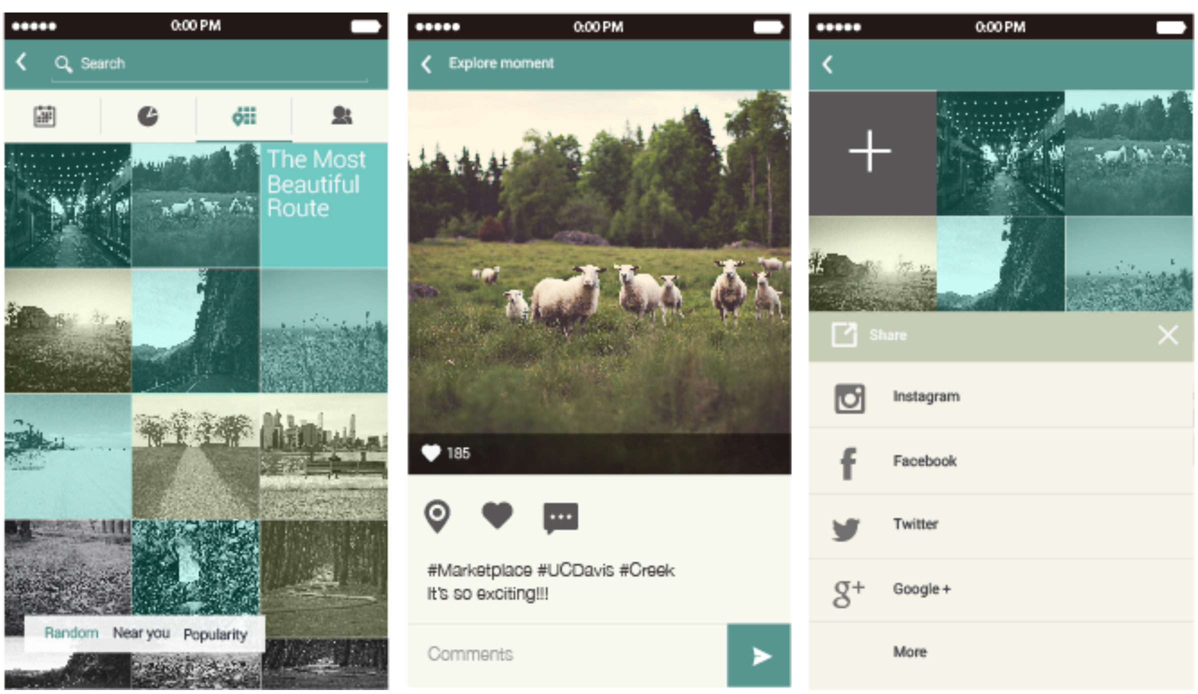

FIGURE 7 Screen design for exploring photos shared by other people

Most of conventional travel mode services focus on the most shortest and efficient route searching. However, this approach is disadvantageous for biking and walking which is relatively less efficient in terms of time management and convenience. Thus, Trip Tracker introduces new way of sharing and searching routes. Users are able to share beautiful photos they took on the trips and share it with key words (e.g., #happy). Similar to social network services such as Instagram and Facebook, users can search route with any keywords. They also can randomly see photos of other users and give comments on it. This approach could shift people's attention away from economic concerns such as time, money and even efficiency toward quality of life concerns such as enjoyment when they are choosing transportation modes. This process would also make people's attitudes regard to biking and walking more favorable; and thus modify intentions and lower the rate of car use. Moreover, people feel more connected to nature and are more concerned about nature by exposing beautiful photos of nature, so that they can be motivated environmentally friendly behaviors.

3. Creating Social Influence and setting a goal to motivate behavior

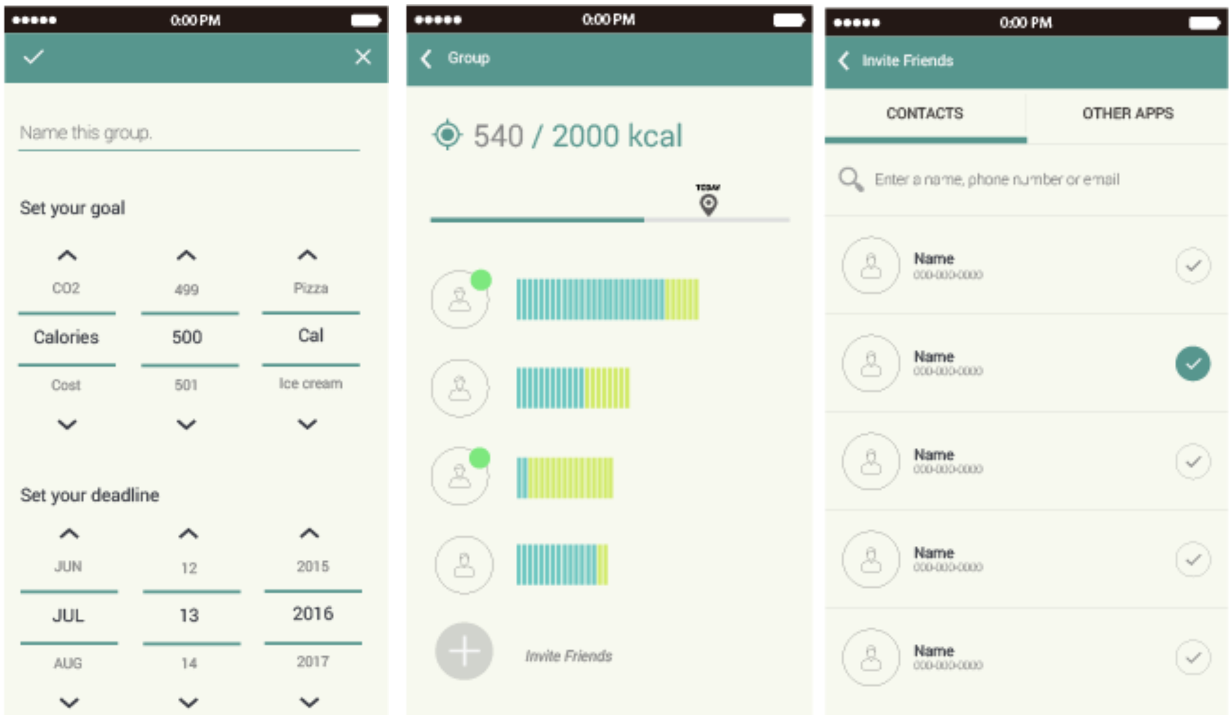

FIGURE 8 Goal setting, Group, Inviting friends

Group function of Trip Tracker creates social influence. According to B.J. Fogg (2003), people can generally achieve a greater degree of attitude and behavior change working together than working alone." He emphasizes the power of social influence through four prominent theories: social facilitation, social comparison, peer pressure, and social learning theory (Fogg, B., 2003). So, the app allows other people to be present in a virtual social group so it can be used to inspire better behavior and make a commitment to reduce car use. Moreover, people normally care about how they will be seen to others. Likewise, people have natural drive to compare with others to determine what they should be thinking and doing. People seek the performance of others, especially others who are similar to themselves, and they will have greater motivation to change their behavior or attitude if they know about the behaviors of others (Fogg, B., 2003). Thus, information about the user's performance compares with the performance of others will derive people to do target behavior. This function can also create **peer pressure** to change people's attitudes and behavior. Because people tend to match the expectations of their "in-group" such as classmates, a team, a family, a work group, or other groups, they will be likely to adopt or avoid performing a target behavior (Fogg, B., 2003). This is also related to the study by Cialdini, B. (2007), taxonomy of persuasive mechanisms. One of the persuasive mechanisms that he formulated is that people are strongly influenced by what others, especially friends and peers, are doing (Ramachandran, D., L., 2010). Moreover, in order to motivate target behavior, the app allows setting the goal and deadline. This will help to create intrinsic motivation for users. According to McGonigal, the characteristics of games such as goal, feedback system, voluntary participation and social connection will create intrinsic motivation **(**Diewald el al. 2015)**.**

Trip Tracker Field Test

To assess the overall impact of Trip Tracker, I compared changes before and after use of Trip Tracker in terms of mode choice behavior and behavioral predictors from the behavior theory that I tested through the survey includes: a) current willingness to commitment to drive less for short trips, b) expectancies of their choice, c) how they feel attached to car, d) normative beliefs, and e) personal environmental value

Data were collected from 11 participants at University of California, Davis; eight were students and three were a faculty. Six were female and five were male aged between18 to 44. To be eligible, the candidates had to be the owner of the vehicle and android mobile phone because Trip Tracker only supports Android OS. Participants were provided $10 gift cards for completing the study. The experiment procedure consisted of 8 days baseline period and 8 days experimental period. At the start and end of the study, participants were asked to complete an online survey that included questions assess each predictor of the behavior theory, willingness to shift driving to walking and biking, their motivations for mode choice, and actual mode choice behavior.-The beta version of Trip Tracker that I used for testing was developed from February 26th to May 10th. As a result of time constraint on developing the app, the function of inviting friends in the group menu was not allowed in the first version of the app. It only allows self-set goal. At the beginning of baseline test, participant downloaded Moves, a smartphone application automatically tracks walking, biking and transporting. The aim was to understand participants' current travel mode choice behavior such as daily frequency, duration and distance. After 8 days baseline period, all participants downloaded Trip Tracker and use it for 8 days.

Mode choice behavior change

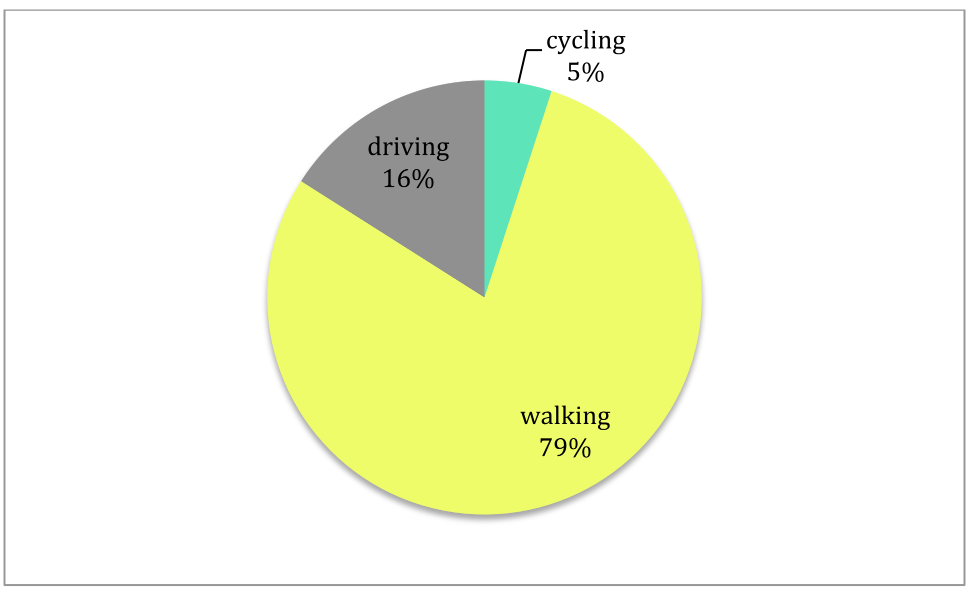

FIGURE 9 Travel events during the baseline period

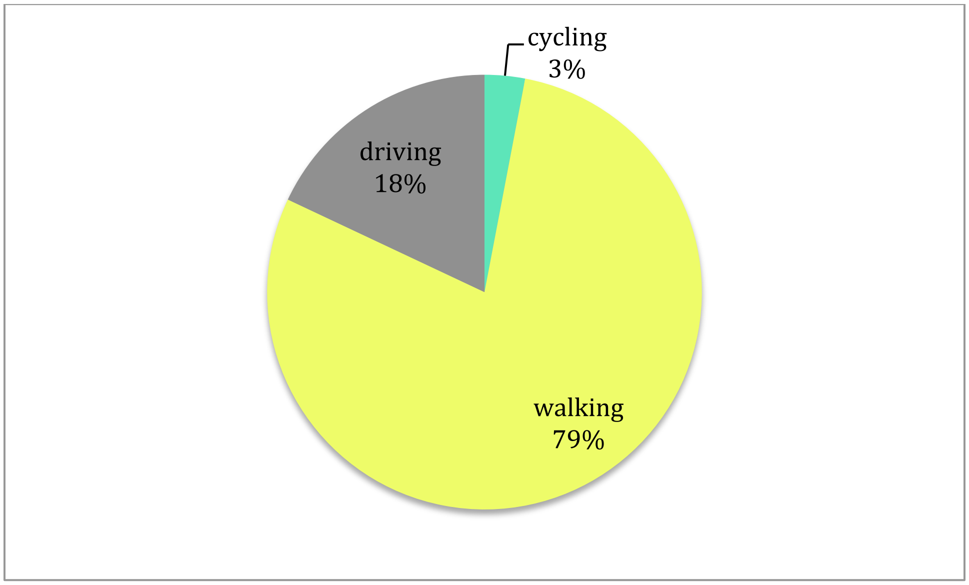

FIGURE 10 Travel events during the testing period

During the baseline period, total travel events were 1,978. Among the total events, 97 (5%) were cycling, 1,566 (79%) were walking, and 315 (16%) were driving. This is 23 travel events per day on average across participants (19 of which were biking and walking). The average trip length was 77 minutes. The average trip length by foot and bike was **56 minutes**. During the testing period, total travel events were 1,929. Among the total events, 67 (3%) were cycling, 1,515 (79%) were walking, and 347 (18%) were driving. The average trip length of all three modes was 74 minutes. The average trip length by foot and bike was **90 minutes. The result showed that there is not much difference on frequency of trips with each mode. However, since the total trip distance by foot and bike has increased 56 minutes to 90 minutes after using Trip Tracker, it demonstrated that the effectiveness of the app on transportation mode choice behavior.**

Behavioral Control

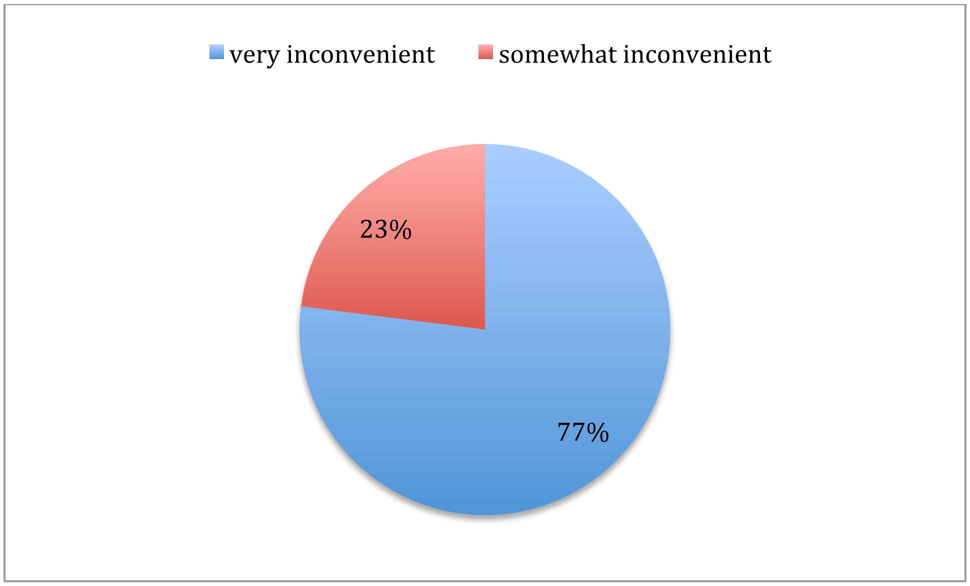

FIGURE 11 Behavioral control before using Trip Tracker

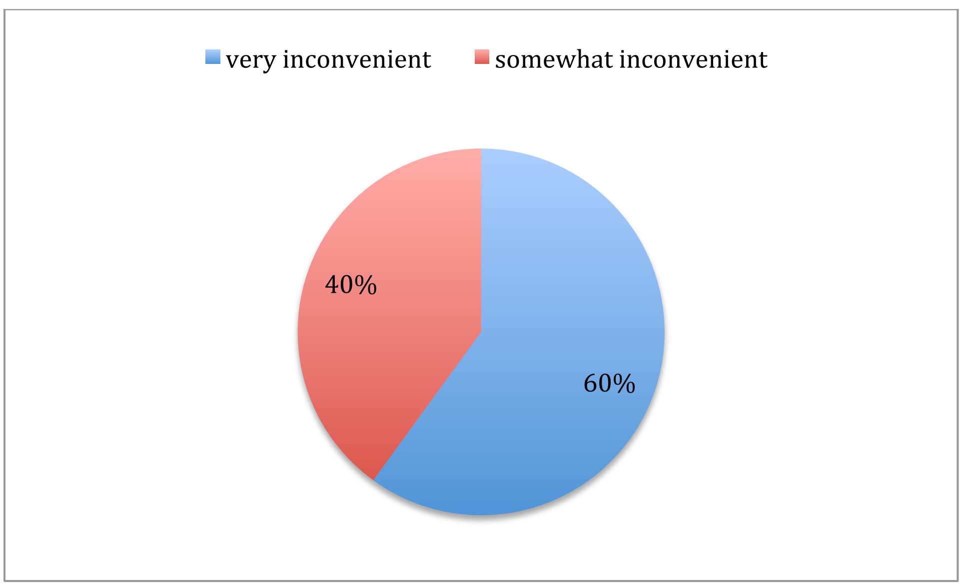

FIGURE 12 Behavioral control after using Trip Tracker

When asked about how inconvenient you would be if you could no longer travel by car, 77% respondent selected very inconvenient, 23% selected somewhat inconvenient, and 0% selected not a problem. After using Trip Tracker, 40% respondent selected very inconvenient, 60% selected somewhat inconvenient and 0% selected not a problem. The result indicates that Trip Tracker reduces the psychological attachment to driving.

Perceived Normative Belief

15% respondent think that they drive more than other people, 38% think about the same, 38% think they drive less than other people, and 8% said not sure. After using Trip Tracker, 18% respondent think they drive more than other people, 55% said about the same, 27% think they drive less than other people, 0% said not sure. This changes in normative belief demonstrates that users start understanding their actual mode choice and its impact more objectively. For example, one participant said, “I bike farther than I thought”. However, since the version of the app used for testing was not fully functioned especially group function, further test on normative belief needs with fully functioned app.

Environmental Value

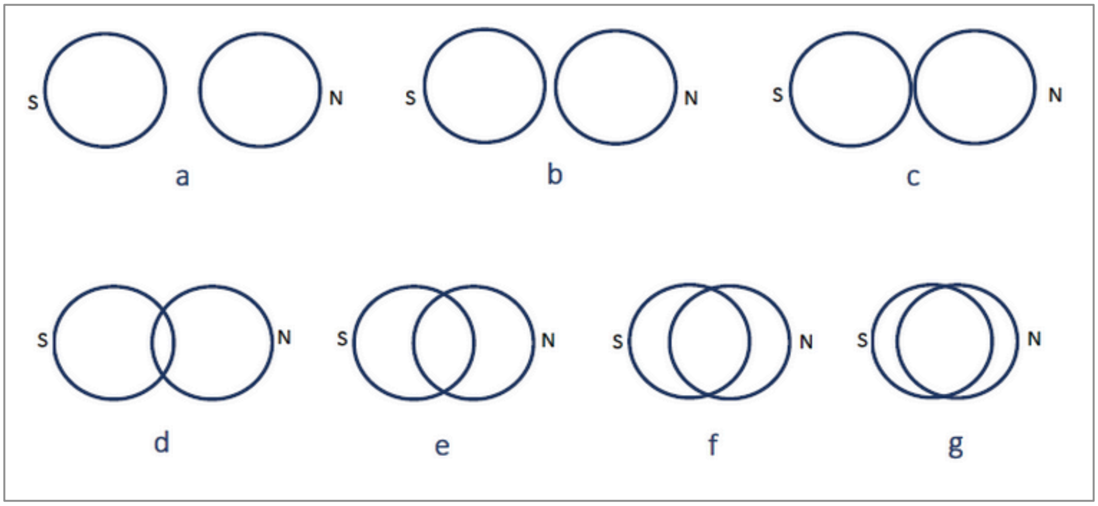

FIGURE 13. The Inclusion of Nature in Self Scale.

To see changes in individual environmental values, I used Schultz's inclusion of nature in self scale (INS; Schultz, 2002). The scale contains a series of seven overlapping circles labels "self" and "nature". This scale measure how individual includes nature within his or her cognitive representation of self (Schultz, P. W. 2001). Participants were asked to "Which image above best describes your relationship with nature? In other words, how interconnected are you with the natural environment? (S = Self; N = Nature)" I converted diagram choice to alphabet letters (a = least overlap, g = greatest overlap).

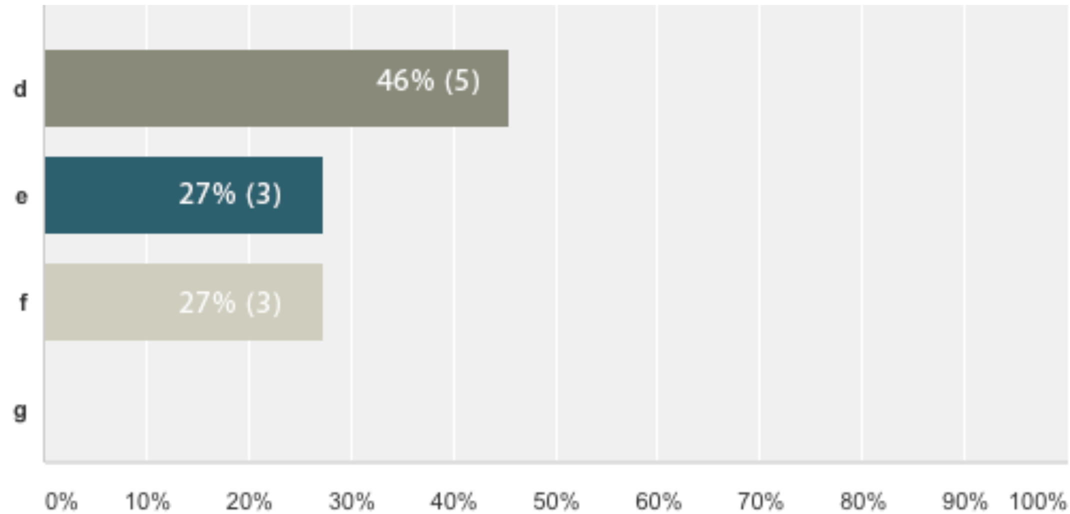

FIGURE 14. INS before using Trip Tracker

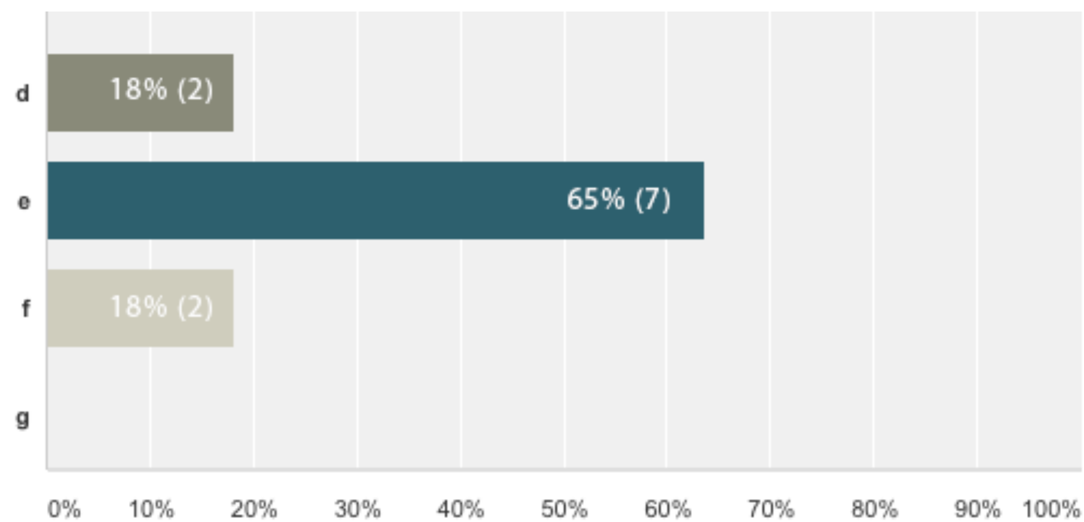

FIGURE 15. INS after using Trip Tracker

The results indicate seven participants did not change perceptions of their relationship with the environment; three participants changed their perception to one level greater inclusion of nature in the self, and one person reported one level lower connectedness after using Trip Tracker.

Awareness of behavioral consequences

Participants were asked to "How knowledgeable are you about the following characteristics of your TRAVEL MODES? Please consider walking and biking for transportation only, NOT solely for exercise or recreation." Participants responded on a 5-point scale, where 1=No Idea, and 5=I could tell you exactly. No significant changes found on awareness of behavioral consequences.

	No idea	I have a rough idea	Somewhat knowledeable	Very knowledgeable	I could tell you exactly!	Total	Weighted Average
Amount of gas your driving consumes	0.00% 0	9.09% 1	18.18% 2	54.55% 6	18.18% 2	11	2.91
Money you spend to fuel your vehicle	0.00% 0	0.00% 0	9.09% 1	72.73% 8	18.18% 2	11	3.09
Amount of carbon dioxide your driving emits	63.64% 7	18.18% 2	18.18% 2	0.00% 0	0.00% 0	11	1.36
Distance you drive	9.09% 1	9.09% 1	36.36% 4	18.18% 2	27.27% 3	11	2.64
Distance you walk	0.00% 0	27.27% 3	36.36% 4	36.36% 4	0.00% 0	11	2.36
Distance you bike	9.09% 1	18.18% 2	9.09% 1	45.45% 5	18.18% 2	11	2.73
Time you spend driving	0.00% 0	18.18% 2	27.27% 3	27.27% 3	27.27% 3	11	2.82
Time you spend walking	9.09% 1	9.09% 1	36.36% 4	36.36% 4	9.09% 1	11	2.45
Time you spend biking	9.09% 1	18.18% 2	18.18% 2	45.45% 5	9.09% 1	11	2.55
Calories you burn traveling by foot	54.55% 6	9.09% 1	18.18% 2	9.09% 1	9.09% 1	11	1.73
Calories you burn traveling by bike	63.64% 7	9.09% 1	0.00% 0	18.18% 2	9.09% 1	11	1.73

FIGURE 16. Results of awareness of behavioral consequences (before using Trip Tracker)

	No idea	I have a rough idea	Somewhat knowledeable	Very knowledgeable	I could tell you exactly!	Total	Weighted Average
Amount of gas your driving consumes	0.00% 0	18.18% 2	36.36% 4	18.18% 2	27.27% 3	11	2.73
Money you spend to fuel your vehicle	0.00% 0	0.00% 0	27.27% 3	36.36% 4	36.36% 4	11	3.09
Amount of carbon dioxide your driving emits	54.55% 6	36.36% 4	9.09% 1	0.00% 0	0.00% 0	11	1.45
Distance you drive	0.00% 0	18.18% 2	18.18% 2	27.27% 3	36.36% 4	11	3.00
Distance you walk	0.00% 0	18.18% 2	36.36% 4	36.36% 4	9.09% 1	11	2.55
Distance you bike	0.00% 0	18.18% 2	9.09% 1	54.55% 6	18.18% 2	11	2.91
Time you spend driving	0.00% 0	9.09% 1	36.36% 4	45.45% 5	9.09% 1	11	2.64
Time you spend walking	0.00% 0	18.18% 2	45.45% 5	27.27% 3	9.09% 1	11	2.45
Time you spend biking	0.00% 0	9.09% 1	18.18% 2	54.55% 6	18.18% 2	11	2.91
Calories you burn traveling by foot	36.36% 4	54.55% 6	0.00% 0	0.00% 0	9.09% 1	11	1.82
Calories you burn traveling by bike	36.36% 4	36.36% 4	9.09% 1	0.00% 0	18.18% 2	11	2.00

FIGURE 17. Results of awareness of behavioral consequences (after using Trip Tracker)

Lastly, at the end of the study I asked to share anything they learned from using Trip Tracker. In open-ended responses on our exit questionnaire, participants gave specific answers about changes they had made. P1 wrote " I feel like the more cars are on the road the more pollutants are going into our environment. So if I can drive less that is a positive impact to the environment and every little bit counts." P10 reported "I think I mainly drove to the hospital in Sacramento to volunteer but other times I drove I realized it was really unnecessary. I can easily bike or take the bus” P9 wrote “It made me more aware of the short trips”. P8 wrote “I’m now more aware of the shorter distances I drive, and how they would be bikeable if I made the effort”. Also, P5 wrote “ The information about pounds of CO2 saved and used was interesting, I hadn’t thought about my transportation in that way before”

Overall, the field study demonstrated that Trip Tracker app increased biking and walking, and lessened psychological attachment to driving. Also, participants started thinking short trips and impact of their mode choices as a prerequisite for behavior change. However, some participants still felt that the app didn’t help to change their attitude towards toward travel mode choices. For example, one participant said “…C02 emissions depends on the vehicle, so I couldn't take the value given as true.” Therefore, more accurate calculation is needed for further study.

Conclusion and future work

In this paper, I researched the issues on automobile dependency, and reviewed the behavioral theory to understand psychological process on individual’s transportation mode decisions, which led to the development the combinations of theoretical construct. I also present results from the preliminary survey testing applicability of the theory to the specific study context. As a result of these formative studies, I developed Trip Tracker, a mobile application prototype that tracks everyday transportation mode choice, gives feedback in terms of various metrics and allows setting a goal. I described the results of a 16 days field study of the use of the prototype with 11 participants. The results of the test demonstrated that the app is viable approach for changing travel mode choice behavior. However, it is hard to confirm that awareness of behavioral consequences and perceptions of relationship with the nature have been changed since the app development is in early stage.

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