TripAware: Emotional and Informational Approaches to Encourage Sustainable Transportation via Mobile Applications

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ABSTRACT

To combat climate change, we need to change user transportation behavior to be less carbon intensive. Prior work on motivating this behavior change has been predominantly qualitative and lacks comparison. This makes it challenging to determine which interventions should be deployed at scale. The behavior change community needs a process to compare interventions against each other in pilot studies before committing deployment resources.

We perform the first quantitative comparison, to our knowledge, of behavior change strategies in the transportation behavior domain. Since this is a pilot with a limited recruitment budget, we design a Randomized Controlled Trial (RCT) using an open source platform. We assign 41 users to three mobile applications: *Emotion*, *Information*, *Control*. The RCT allows us to draw statistically valid inferences that can suggest future avenues for larger-scale studies.

We found that *Emotion* resulted in greater engagement with the application ($p=0.006$, 0.035 , 0.031 , 0.040) while *Information* improved the sustainability of travel behavior ($p = 0.043$). These exploratory statistical results can motivate the design of future studies to further explore combinations of these approaches for sustainable transportation behavior.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in ubiquitous and mobile computing**; *HCI design and evaluation methods*; Empirical studies in interaction design; • **Applied computing** → **Psychology**.

KEYWORDS

mobile applications, carbon emissions, transportation behavior

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1 INTRODUCTION

There has been extensive prior work, both in academia and industry, on motivating individuals to reduce their transportation emissions. However, a careful review indicates problems in their evaluations that would make it difficult to draw conclusions to motivate future, large-scale studies. Concretely, the evaluations are mainly qualitative, lack comparison or statistical testing of user engagement, and are missing emissions reduction metrics. Therefore the novelty of our exploratory study is to provide quantitative, statistical evidence of the effectiveness of behavior change policies in comparison to each other in a randomized controlled trial.

In this paper, we contrast two broad behavioral approaches—Information and Emotion—for utilizing smartphones to encourage environmentally sustainable transportation habits. This is premised primarily on the behavior change wheel [5] and related studies [3, 6]. Our application, *TripAware*, is built upon the open-source E-mission platform, allowing it to seamlessly track and classify user trips in the background on a secure server [8] and making it easy for future studies to follow a similar approach.

We will outline our two test applications, *Information* and *Emotion*, which calculate carbon emissions from transportation and utilize separate behavior-changing features in a randomized controlled experiment. We begin with discussing our motivation for the groupings and related literature. This is followed by the challenges and limitations within our experiment, our design decisions, and finally our results and their for future studies.

2 MOTIVATION AND RELATED WORKS

2.1 Motivation

During the design stage of our experiment, we focused heavily on rooting our design decisions in a coherent model of human behavior.

The behavior change wheel (BCW) addressed our needs for such behavioral models, matching types of behaviors with well-suited interventions while being consistent with other works [3, 5, 6]. As a result, we constructed our experiment around two main sources of behavior outlined in the BCW. We ask, how much will people change their transportation habits if they're explicitly shown sustainable alternatives, as compared to if they are taught to feel negatively about unsustainable modes of transportation and positively about sustainable ones? The informational approach presumes that the people generally want to change their transportation behavior, and just need to be shown how. The emotional instead attempts to make people emotionally driven towards changing their transportation habits.

2.2 Advancing Current Literature

We analyzed many similar studies (separate document with 21 more studies not listed in this paper found here [12]), and found several issues present in most.

2.2.1 Comparison under a Randomized Controlled Trial (RCT). The vast majority of studies did not provide a comparison between methods, and none of them provided a comparison between the two approaches we highlight. Furthermore, most were not performed under an RCT. Exploratory studies like ours usually cannot acquire the sample sizes required to achieve great statistical power in their analysis, so we performed an RCT to be able to provide statistical evidence of our comparisons. UbiGreen, which explored how visual feedback of a user's transportation behaviors would help to support greener transportation choices, had 13 and Matkahupi, which utilizes gamification to engage and motivate users to change their behaviors sustainably, had just 7 [2, 4].

2.2.2 Lack of Quantitative, Statistical Results. None of the papers that implemented an application similar to ours measured the actual change in users' emissions and then performed statistical testing on them. Our study design allows us to do this, and we also kept track of other metrics related to behavior change and app interaction; furthermore, we perform statistical testing on these metrics to infer more about the behavior interventions we compared.

2.2.3 Feature Integration Under Our Behavioral Framework. The features we chose to implement within our application were inspired largely from related studies, although we also introduced some new ones. For example, the polar bears were inspired by many previous studies. Zapico et. al presented an early concept, Dillahunt et. al realized that bear animations led to more user engagement and care for the environment, and in Eco-Island participants were motivated to save their sinking in-game island [1, 9, 10]. In response to Ubigreen's suggestions, we implemented community interaction and individualized user carbon information.

2.2.4 Tying it All Together. With the flexibility of the E-mission platform and modern smartphones, we reduced required user engagement while improving upon successful features, and we demonstrate the ease of performing this type of comparison based RCT with an open-source platform (E-mission). In summary, this exploratory study fills a gap in the current literature by demonstrating the need for such a method while also producing statistically relevant results in the context of transportation behavior change

Figure 1: The diary and detailed trip information screen. The diary displays trips on a map, what modes of transportation were used, duration, speed, and total emissions.

that future, larger studies can utilize to motivate their experiment design.

3 IMPLEMENTATION

From previous literature and our behavioral framework, we identified two main types of persuasive feature groups: *Information* and *Emotion*. *Information* features primarily focused on providing direct feedback on user behavior while *Emotion* features leveraged people's emotions as a motivating factor. We developed three mobile applications: *Control*, *Information*, and *Emotion*. The following section will discuss their features.

3.1 Trip Diary

A trip log is present in all experiment groups and serves as the only feature for the control group. See Figure 1 for more information.

3.2 Carbon Intensity

Instead of raw carbon emissions, we use a metric defined as *carbon intensity* to calculate users' emissions. We came up with this metric to serve as a more equitable representation of a user's carbon emissions; this is explained in depth in *The Walking College Student Problem* section. The equation and its derivation can be found in our techreport [11].

3.3 Tiered System

Schultz et al. [7] discovered that people started to care less about their energy consumption when told that they were consuming less than average (the "boomerang effect").

Therefore we created a tiered leaderboard system for this study. *TripAware* attempts to reduce the boomerang effect by grouping together people with similar performances. Since top performers will be compared to other top performers, they will not feel as "ahead" as they would when compared to the average user. On the other hand, users who rank low on the tier system will not be as discouraged since they will be compared to similar users. See Figure 2 for more details.

Figure 2: *Left*: The control dashboard. *Right*: The tiered leaderboard system, which ranked users by their *carbon intensity* and divided into three tiers, with usernames shown.

3.4 Control Group

We sought to minimize the control application’s influence on users’ travel patterns. Subjects in the control group were given a bare UI with only a trip diary. See Figure 2.

3.5 Information Group

With the *Information* app’s motivations in mind, we decided that the following were vital issues to address. Users should:

- (1) Receive suggestions on *how* to reduce emissions.
- (2) Know their carbon footprint; receive appropriate feedback.
- (3) Be able to view past trips and see their carbon impact.

The first section of the dashboard addresses the first problem by displaying a suggested trip for the user based on the distances of their recent trips and suggests an appropriate, greener alternative.

Below the suggestion is the “Weekly Stats” section. It gives users a summary of their recent performance, addressing problem two.

Finally, the “Recent Trips” section addresses the third issue. A small summary is displayed for the three most recent trips. See the right image of Figure 3 for a more detailed look at the dashboard.

3.6 Emotion Group

The centerpiece of the *Emotion* application is the polar bear, used to evoke environmental empathy.

Polar bear size is an indication of performance consistency. The polar bear became larger to reflect long term emissions reduction, and smaller to reflect an increase in long term emissions.

Its mood is an indication of short-term performance and changed depending on the previous day’s carbon emissions. We hypothesized that the polar bear’s ability to change mood would make people feel guilty or happy in response, motivating their behavior. See Figure 3 for a look at the polar bear and dashboard.

4 DESIGN DECISIONS

When implementing the aforementioned features, we encountered problems and made key design decisions for our applications. The

Figure 3: Dashboards: *Left*: Emotion *Right*: Information Polar bears were grouped on different islands where each island represented the user’s tier. A user’s bear is always visible along with and four other random bears from their tier.

following section will describe these challenges and outline appropriate solutions and our decisions.

4.1 Walking College Student Problem (WCSP)

Certain lifestyles will lead to lower carbon intensity values and will be advantageous for leaderboard rankings. For instance, a typical college student can dominate the Tiered System as their classes and responsibilities are all within walking distance.

We decided the best solution to WCSP was a reward system that decreases a trip’s carbon intensity if its distance is above a certain threshold. This approach aims to both mediate differences between individuals with shorter and longer commutes and persuade users to use more sustainable modes of transportation when traveling small distances. More details are found in our techreport [11].

4.2 Focus on Transportation Emissions

We focused only on tracking transportation emissions and how their respective reductions corresponded to their changes in transportation habits. Extra features would require necessary user input which could lead to reduced user engagement.

5 RECRUITING AND RESULTS

Our study received ethics clearance by an IRB approval process. We initially believed that emphasizing a monetary incentive (a chance to win \$50) would interest people to join the study; however, this may have equally detracted from the site’s legitimacy. Upon downloading *TripAware*, our 41 participants were randomly assigned to one of the three groups. The majority of the participants were 18-30 years old and the median reported income was between \$100,000 - \$200,000. More details can be found in our tech report [11].

Before analyzing our results, we had to reduce our sample size where applicable by removing users who did not have the statistic recorded. This resulted in an absolute minimum of 18 people across all tests.

5.1 Hypothesis Testing

For all relevant analyses, we performed a permutation test to test the null hypothesis that the observed difference in means of the statistic being measured across the two groups being compared was due to random chance, using a p -value of 0.05.

5.2 Analysis

We present five different metrics split into two categories: app interaction and behavior change. For all metrics, permutation testing compared differences in averages across groups. More statistics can be found in our techreport [11].

- (1) **Number of App Openings per Person:** *Emotion* and *Information* received a statistically significant level of interaction as compared to *Control* ($p = 0.006, 0.045$). However *Emotion-Information* was insignificant ($p = 0.189$).
- (2) **Number of Trips Viewed per Person:** *Emotion* vs *Control* resulted in a significant difference ($p = 0.035$). Both other comparisons are insignificant (*Information-Control*: $p = 0.133$ and *Emotion-Information*: $p = 0.183$).
- (3) **Retention Duration:** On average, *Emotion* users used the app for 53.067 days, *Information* users 30.644 days, and *Control* users 27.606 days. We conclude statistical significance between *Emotion* and *Control* and *Emotion* and *Information* ($p = 0.031, 0.040$ respectively), but not *Information-control* ($p = 0.398$).
- (4) **Change in Carbon Intensity:** Intuitively, change in carbon intensity is represented by users' normalized change in carbon intensity over time. *Control* resulted in -11.61% change, *Emotion*: -33.68%, and *Information*: -54.71%. There is no significant difference between *Emotion* and *Information* ($p = 0.139$) and *Emotion* and *Control* ($p = 0.116$), but there is a significant difference between *Information* and *Control* ($p = 0.043$). This is as expected as there is a large difference between *Information* and *Control*, but *Emotion* is in between.
- (5) **Change in Transportation Modes:** Intuitively, change in transportation mode for each user is represented as a normalized value of how each transportation mode changed over time. All combinations of group and transportation modes had p values far above a 0.05 threshold.

5.3 Limitations of the Study

Although this study had enough participants for statistical testing, there is always a need for more participants in these studies. Furthermore, the study lasted for ten weeks; it could have benefited from a longer period. There is also potential user bias: perhaps people who cared more about reducing their emissions clicked on our ads, although we tried to offset this with a monetary incentive.

6 CONCLUSION

Both *Emotion* and *Information* have statistically significant effects on users' behaviors when compared to the control application. Generally, emotional features kept the users more engaged (number of app openings, number of trips viewed, and retention duration), while informational features caused a significant emissions reduction (change in carbon intensity). Our results illuminate possible behavioral influence from each set of features but are likely not

sufficient to fully explain the effectiveness of the two sets when compared to each other.

Tying in our behavioral framework and our original question, we observe that explicitly demonstrating ways to change behavior and displaying personalized statistics (*Information*) led to real emissions reductions, while appealing to emotional sources of behavior (*Emotion*) led to increased user engagement but no significant emissions change. Our comparisons' results can motivate future, larger studies to combine these features in order to target specific behaviors to produce more statistically powerful results that will provide even more insight into how to tackle transportation behavior change.

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