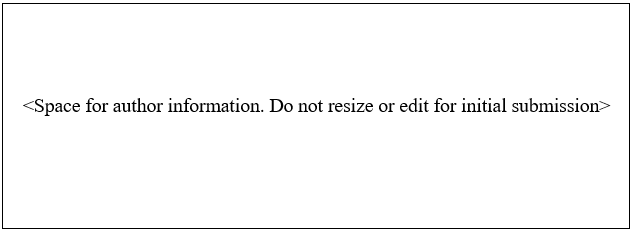
**The Impact of Mobile App Usage on Individual Behavior Changing: An Experimental Study of Driving Behavior**

*Research-in-Progress*

****

**Abstract**

*Information technology (IT) has been widely used in business, entertainment and public health, and its application in the field of environmental protection is emerging in recent years. Many studies have been devoted to developing IT products that are more appealing to the masses, or to measuring the value of IT to an industry or organization. However, research on using IT and mobile app in particular to change individual behavior is still relatively young. Given the lack of a picture of the way mobile app can have impacts on individual behavior, we plan to conduct a natural experiment of 63 taxi drivers in a year or so from July 2019. We will record participants’ app usage behaviors and monitor their driving behaviors, especially the CO2 emissions, in a given day. This paper discusses implications of the findings, identifies gaps in the literature and provides a roadmap for future research.*

**Keywords:** mobile app usage, CO2 emissions, individual behavior changing

# Introduction

There is a growing emphasis on global effects of various air pollutants, especially for greenhouse gases and notably CO2. Road vehicles are acknowledged to be significant sources of a range of pollutants. In 2018, they were responsible for 25% of total CO2 emissions from fuel combustion[[1]](#footnote-1) (IEA 2020). And poor driving habits can even lead to more vehicle emissions (Alessandrini et al. 2012; Van Mierlo et al. 2004). Then since the mid '90s, eco-driving has been developed as a new approach to driving, and nowadays it is a climate change initiative not to be overlooked (Alessandrini et al. 2012; Barkenbus 2010).

But it is far from enough to be satisfied with the help of initiatives or suggestions. With the development of Internet of vehicles (IOV), increasingly more organizations including government agents and IT companies are paying attention to leverage information technology (IT) to improve driving behaviors and cutting down CO2 emissions.

It is acknowledged that the diffusion and deepening of the IT revolution is a hallmark of the emerging ‘information age’ (Castells 1997). And the rapid development of IT brings many gadgets with it, such as smartphones, personal computers, mobile apps and so on (Joorabchi et al. 2013; Mahmood et al. 2001; Nishad and Rana 2016). People use these IT products and applications for different purposes. And not surprisingly, as people use IT more frequently, researchers are studying the effects with growing interest (Greengard 2011).

Early studies have put more emphasis on their positive effects, including promoting the development of health care, education, business, communication, entertainment and global connectivity (Chen 2020; Cole-Lewis and Kershaw 2010; Green and Bavelier 2008; Hitt and Brynjolfsson 1996). As the research progressed, some researchers start trying to use IT to influence human behavior (Årsand et al. 2010; Hebden et al. 2012; Hughes et al. 2010; Mattila et al. 2009; Sundaram et al. 2007; Varnfield et al. 2011). However, there is still a lack of its application on the purpose of environmental protection. Thus, we planned to carry out a natural experiment to observe the changes in drivers’ driving behavior and to assess the environmental value of IT usage.

# Literature Review

## IT Usage and Behavior Changing

A typical objective of most prior IT research is to explain the factors influencing the IT usage and acceptance. In the last decades, researchers have built and tested several theorical models of IT usage, such as *theory of planned behavior* (TPB), and the *technology acceptance model* (TAM) (Taylor and Todd 1995; Venkatesh et al. 2003). Another major objective of IT research is to assess its business value. Studies shows that IT usage is a key driver of good organizational performance and can effectively improve productivity (Devaraj and Kohli 2003; Hitt and Brynjolfsson 1996).

Meanwhile, only a few researchers have reported on the use of IT products and applications for individual behavior changing. Research is usually seen in some certain fields like public health and business. In the field of public health, Mattila et al. tried to record self-management of weight-related behaviors (Mattila et al. 2009), Hughes et al. developed an app for monitoring energy balance (Hughes et al. 2010), and others have monitored diet or physical activity as part of a program for diabetes (Årsand et al. 2010) or cardiac rehabilitation (Varnfield et al. 2011). When it comes to commercial field, Sundaram et al. suggested that the effective and efficient use of technology enhances salesperson performance (Sundaram et al. 2007). And according to Hebden et al., software applications used on mobile devices (mobile apps) are a novel technology that can be used to deliver behavior change interventions directly to individuals and have the potential to make a difference (Hebden et al. 2012).

Actually, IT can change even more than that. As environment and sustainability have been supposed to become game-changing megatrends in the near future (Lubin and Esty 2010), new thinking and innovation is urgently required. Green IT is put forward in this context. Prior researchers defined Green IT as the systematic application of practices that enable the minimization of the environmental impact of IT and allow for company-wide emission reductions based on technological innovations (Pablos 2012). It essentially covers two goals, including reducing the amount of emissions released by IT systems and infrastructure, and reducing the emissions from business and production processes with the aid of IT. We will benefit a lot from Green IT such as saving our money, improving energy efficiency, lowering greenhouse gas emissions and so on (Erek et al. 2011; Loeser et al. 2011; Murugesan 2008).

As little research explored the Green IT in terms of human driving behaviors, this study will investigate the relationship between individual level environmental impacts (CO2 emissions) and App usage behavior of drivers.

## Driving behavior and CO2 emissions

CO2 emissions from road transport are of special concern, as they have been rising constantly (Gorham 2002). Some studies (Idso et al. 1998; Nasrallah et al. 2003) have measured and considered levels of CO2 to be representative of air quality similar to other pollutants that can have significant health effects (e.g. NOX, SO2, CO and PM10 ). In this respect, it is about time researchers researched on how to reduce CO2 emissions from road transport.

In addition to better transport infrastructure, advances in vehicle technology and management systems (Nejadkoorki et al. 2008), better driving style can effectively reduce greenhouse gas emissions as well. Alessandrini et al. have shown that drivers who push the accelerator pedal in a steadier way will consume and emit less (Alessandrini et al. 2009). Gao et al. analyzed fuel consumption and NOx emission characteristics over various scenarios, and provided the guidance for eco-driving to achieve cleaner travelling (Gao et al. 2021). And the influence of driving style on the environment has finally been proved directly by Alessandrini et al. with an on road campaign (Alessandrini et al. 2012).

Therefore, one of the possible actions to reduce the environmental impact caused by road transport is to educate drivers to adopt a driving style that is as eco-friendly as possible. And we will use in-car sensor data and a natural experiment to build regression models to see how each contributing factor relates to CO2 emissions.

# Theoretical Foundations

Although research on the impact of mobile apps on individual behavior is still relatively young, theory on factors for arousing and directing a person’s behavior has already existed (Halepota 2005; Iso-Ahola 1980), and the theory is emerging as an appropriate lens for its examination (Chang et al. 2013; Lee et al. 2005). Motivational theories are such a group of theories, most of which differentiate between intrinsic and extrinsic factors: the former are concerned with the performance of an activity for no apparent reinforcement other than the activity per se. Extrinsic motivations focus on the outcome of the activity i.e. individuals are driven by the outcome rather than the activity itself (Deci and Ryan 2010; Moon and Kim 2001; Ramayah et al. 2003).

In the past decades, people’s intrinsic and extrinsic drives have been utilized to account for individual behavior. For example, researchers put perceived enjoyment, perceived ease of use as intrinsic motivation while perceived usefulness as extrinsic motivation of Internet usage (Lee et al. 2005; Moon and Kim 2001; Ramayah et al. 2003; Teo et al. 1999; Zhang et al. 2008). And in the realm of eco-driving, referring to Steg and Vlek (Steg and Vlek 2009), pro-environmental behaviors can be motivated by informational strategies aiming to influence perceptions and knowledge, and structural strategies aiming to change external factors such as policy and technology.

Meanwhile, previous research also points out that behavior interventions that affect the antecedents of behavior are less effective than those that affect consequences (Flemming et al. 2008). Antecedent strategies aim to modify the determinants of behavior such as attitudes and knowledge, whereas consequence strategies aim to incentivize behavior through feedback (Potvin-Bernal 2020).

Thus, since the goal of our work is to explore the impact of mobile app usage on individual behavior changing, after understanding humans’ behavioral motivation, we plan to design our experiment and explain the results based on the prior theories. In our research, the participants will have access to a mobile app which will send alert to them when it detects risky driving behaviors and provide a driving behavior ranking at the end of the day. Considering that the app has feedback and reminder function, we will take the app as a prime extrinsic motivator for individual behavior changing. Besides, the willingness (intrinsic motivation) of using our app and improving their driving behavior vary from person to person. Thus, different behavior of app usage can also reflect different participants’ intrinsic motivation for changing behaviors.

In short, as our participants’ different behavior of app usage and actual changes of driving behavior can be clearly observed, the experiment is definitely feasible and reasonable.

# Experiment Design and Hypotheses Development

## Natural Experiment Design

We plan to use a factorial experimental design for a total of 4 different groups. The treatments will be app usage (yes versus no), and driving experience (novice drivers versus experienced drivers). Our research methodology is illustrated in Figure 1.

|  |
| --- |
|  |
| **Figure 1. Research Methodology** |

Before the natural experiment, we will first carry out a questionnaire survey to record some demographic variables such as the participants’ age, gender and driving experience. In the experiment, we’ll mainly tested two instruments. One is the drivers’ intrinsic motivation for driving in a better manner, and another will show the extrinsic factor to encourage drivers to driving better. We are to conduct our experiment in the following order:

* According to previous research, we distinguish novice drivers from experienced drivers by their driving experience. The drivers will be automatically divided into Group1 (novice drivers) and Group2 (experienced drivers) bounded by the median of all drivers’ driving experience (Brown and Groeger 1988; Underwood et al. 2003).
* In each separate group, different behaviors of app usage (whether have used or not) in a given day will be observed. And then in the two groups of drivers using and not using app, driving behavior before and after using the app will be measured and recorded respectively.
* Finally, we will assess the impact of app usage on individual behavior changing.

## Hypotheses Development

As the zero-risk model predicts, increasing driving experience and exposure to traffic increases the sense of subjective control and decreases the sense of subjective risk while decreasing concern for safety aspects (Näätänen and Summala 1976). The results of previous studies verify that drivers with less driving experience tend to behave worse than experienced drivers but be more concerned about driving safe and more motivated to improve their driving behavior (Lajunen and Summala 1995). Thus, we hypothesize:

* H1: Drivers with less driving experience (novice drivers) will use the mobile app more.

As is mentioned before, the mobile app provides alerts and feedback on driving performance every day. According to motivational theories, as a form of extrinsic motivation, the mobile app probably could help cut down the CO2 emissions by informing drivers of their driving behaviors. Thus, we hypothesize:

* H2: Mobile app usage behavior of drivers is positively correlated with individual level environmental impacts (measured with total daily CO2 emissions amounts).

# Data Collection and Measures

## Data Collection

In order to eliminate the error caused by different car models, we will recruit 63 different drivers from a Chinese taxi company and collect their driving behavior data in a year or so from July 2019using On-Board Diagnostic (OBD) systems, which have been incorporated into the computers on-board new vehicles to monitor vehicle components and driving behaviors in recent years (Wei et al. 2020; Yang et al. 2016).

Meanwhile, we will provide our mobile app to these 63 taxi drivers and collect their app usage data. We will also collect their demographic information including age, gender and driving experience from the questionnaire survey before the experiment. All drivers will be paid for their participation.

## Measures

Drivers’ driving behaviors will be related to individual level environmental impacts, and measured by the amounts of CO2 emissions (CO2EM) in a given day as the dependent variable. The mobile app usage behavior of drivers (app\_usage) will be the key independent variable of interest in our estimation. It will be used to identify whether a driver has used the app, measured by the driver's check-in status in the app in a given day.

Several control variables are considered to ensure the model robustness. For example, driving experience (driving\_experience) indicates the driving months and intrinsic motivation for driving better of a driver. Tired\_driving refers to hours of tired driving per day, Speed\_KMH refers to average driving speed per day) and Totalmile is the total range that day. The demographic variables including age and gender are viewed as control variables as well.

# Preliminary Contributions

This paper paves the way for future work on empirically investigating the impact of mobile app usage on individual behavior changing. Till now, several studies have been collected and analyzed to help design our natural experiment. We plan to choose CO2 emissions as a measure of driving behavior, and try to explain our experiment design philosophy and the expected results based on motivational theories. We hope the findings of our research can:

* Extend the current understanding of motivational theories.
* Promote further discussion of the positive impact of IT on individual behavior.
* Have implications for future environmental protection projects and assist relevant organizations to develop apps aiming to help energy conservation and emission reduction.

And there are also limitations of the research that:

* The experiment uses data of drivers located in China. In spite of this, given that traffic laws and road conditions vary from country to country, one would expect that the usage of mobile app might play a different role in individual level pro-environmental behavior in other countries.
* Over the past year, the Covid-19 epidemic has had a major impact on all sectors of society and it may have certain influence on drivers' driving behavior along with the app usage, thus causing bias.

# References

Alessandrini, A., Cattivera, A., Filippi, F., and Ortenzi, F. 2012. "Driving Style Influence on Car Co2 Emissions," *2012 international emission inventory conference*.

Alessandrini, A., Orecchini, F., Ortenzi, F., and Campbell, F. V. 2009. "Drive-Style Emissions Testing on the Latest Two Honda Hybrid Technologies," *European Transport Research Review* (1:2), pp. 57-66.

Årsand, E., Tatara, N., Østengen, G., and Hartvigsen, G. 2010. "Mobile Phone-Based Self-Management Tools for Type 2 Diabetes: The Few Touch Application," *Journal of diabetes science and technology* (4:2), pp. 328-336.

Barkenbus, J. N. 2010. "Eco-Driving: An Overlooked Climate Change Initiative," *Energy policy* (38:2), pp. 762-769.

Brown, I., and Groeger, J. 1988. "Risk Perception and Decision Taking During the Transition between Novice and Experienced Driver Status," *Ergonomics* (31:4), pp. 585-597.

Castells, M. 1997. "An Introduction to the Information Age," *City* (2:7), pp. 6-16.

Chang, C.-C., Liang, C., Yan, C.-F., and Tseng, J.-S. 2013. "The Impact of College Students’ Intrinsic and Extrinsic Motivation on Continuance Intention to Use English Mobile Learning Systems," *The Asia-Pacific Education Researcher* (22:2), pp. 181-192.

Chen, C.-Y. 2020. "Smartphone Addiction: Psychological and Social Factors Predict the Use and Abuse of a Social Mobile Application," *Information, Communication & Society* (23:3), pp. 454-467.

Cole-Lewis, H., and Kershaw, T. 2010. "Text Messaging as a Tool for Behavior Change in Disease Prevention and Management," *Epidemiologic reviews* (32:1), pp. 56-69.

Deci, E. L., and Ryan, R. M. 2010. "Intrinsic Motivation," *The corsini encyclopedia of psychology*), pp. 1-2.

Devaraj, S., and Kohli, R. 2003. "Performance Impacts of Information Technology: Is Actual Usage the Missing Link?," *Management science* (49:3), pp. 273-289.

Erek, K., Loeser, F., Schmidt, N.-H., Zarnekow, R., and Kolbe, L. M. 2011. "Green It Strategies: A Case Study-Based Framework for Aligning Green It with Competitive Environmental Strategies," *PACIS*: Citeseer, p. 59.

Flemming, S. A., Hilliard, A., and Jamieson, G. A. 2008. "The Need for Human Factors in the Sustainability Domain," *Proceedings of the human factors and ergonomics society annual meeting*: SAGE Publications Sage CA: Los Angeles, CA, pp. 748-752.

Gao, J., Chen, H., Liu, Y., Li, Y., Li, T., Tu, R., Liang, B., and Ma, C. 2021. "The Effect of after-Treatment Techniques on the Correlations between Driving Behaviours and Nox Emissions of Passenger Cars," *Journal of Cleaner Production* (288), p. 125647.

Gorham, R. 2002. "Air Pollution from Ground Transportation," *An Assessment of Causes, Strategies and Tactics, and Proposed Actions for the International Community. New York: United Nations, Division of Sustainable Development, Department of Economic and Social Affairs*).

Green, C. S., and Bavelier, D. 2008. "Exercising Your Brain: A Review of Human Brain Plasticity and Training-Induced Learning," *Psychology and aging* (23:4), p. 692.

Greengard, S. 2011. "Living in a Digital World," *Communications of the ACM* (54:10).

Halepota, H. A. 2005. "Motivational Theories and Their Application in Construction," *Cost engineering* (47:3), p. 14.

Hebden, L., Cook, A., Van Der Ploeg, H. P., and Allman-Farinelli, M. 2012. "Development of Smartphone Applications for Nutrition and Physical Activity Behavior Change," *JMIR research protocols* (1:2), p. e9.

Hitt, L. M., and Brynjolfsson, E. 1996. "Productivity, Business Profitability, and Consumer Surplus: Three Different Measures of Information Technology Value," *MIS quarterly*), pp. 121-142.

Hughes, D. C., Andrew, A., Denning, T., Hurvitz, P., Lester, J., Beresford, S., Borriello, G., Bruemmer, B., Moudon, A. V., and Duncan, G. E. 2010. "Balance (Bioengineering Approaches for Lifestyle Activity and Nutrition Continuous Engagement): Developing New Technology for Monitoring Energy Balance in Real Time," *Journal of diabetes science and technology* (4:2), pp. 429-434.

Idso, C. D., Idso, S. B., and Balling Jr, R. C. 1998. "The Urban Co2 Dome of Phoenix, Arizona," *Physical Geography* (19:2), pp. 95-108.

IEA. 2020. "Co2 Emissions from Fuel Combustion by Sector in 2018." 2020, from <http://www.iea.org/publications/freepublications/publication/co2-emissions-from-fuel-combustion-highlights-2020.html>

Iso-Ahola, S. E. 1980. "The Social Psychology of Leisure and Recreation,").

Joorabchi, M. E., Mesbah, A., and Kruchten, P. 2013. "Real Challenges in Mobile App Development," *2013 ACM/IEEE International Symposium on Empirical Software Engineering and Measurement*: IEEE, pp. 15-24.

Lajunen, T., and Summala, H. 1995. "Driving Experience, Personality, and Skill and Safety-Motive Dimensions in Drivers' Self-Assessments," *Personality and Individual Differences* (19:3), pp. 307-318.

Lee, M. K., Cheung, C. M., and Chen, Z. 2005. "Acceptance of Internet-Based Learning Medium: The Role of Extrinsic and Intrinsic Motivation," *Information & management* (42:8), pp. 1095-1104.

Loeser, F., Erek, K., Schmidt, N.-H., Zarnekow, R., and Kolbe, L. M. 2011. "Aligning Green It with Environmental Strategies: Development of a Conceptual Framework That Leverages Sustainability and Firm Competitiveness," *AMCIS*: Citeseer.

Lubin, D. A., and Esty, D. C. 2010. "The Sustainability Imperative," *Harvard business review* (88:5), pp. 42-50.

Mahmood, M. A., Hall, L., and Swanberg, D. L. 2001. "Factors Affecting Information Technology Usage: A Meta-Analysis of the Empirical Literature," *Journal of organizational computing and electronic commerce* (11:2), pp. 107-130.

Mattila, E., Korhonen, I., Salminen, J. H., Ahtinen, A., Koskinen, E., Särelä, A., Pärkkä, J., and Lappalainen, R. 2009. "Empowering Citizens for Well-Being and Chronic Disease Management with Wellness Diary," *IEEE Transactions on Information Technology in Biomedicine* (14:2), pp. 456-463.

Moon, J.-W., and Kim, Y.-G. 2001. "Extending the Tam for a World-Wide-Web Context," *Information & management* (38:4), pp. 217-230.

Murugesan, S. 2008. "Harnessing Green It: Principles and Practices," *IT professional* (10:1), pp. 24-33.

Näätänen, R., and Summala, H. 1976. "Road-User Behaviour and Traffic Accidents," *Publication of: North-Holland Publishing Company*).

Nasrallah, H. A., Balling Jr, R. C., Madi, S. M., and Al-Ansari, L. 2003. "Temporal Variations in Atmospheric Co2 Concentrations in Kuwait City, Kuwait with Comparisons to Phoenix, Arizona, USA," *Environmental Pollution* (121:2), pp. 301-305.

Nejadkoorki, F., Nicholson, K., Lake, I., and Davies, T. 2008. "An Approach for Modelling Co2 Emissions from Road Traffic in Urban Areas," *Science of the total environment* (406:1-2), pp. 269-278.

Nishad, P., and Rana, A. S. 2016. "Impact of Mobile Phone Addiction among College Going Students," *Advance Research Journal of Social Science* (7:1), pp. 111-115.

Pablos, P. O. d. 2012. *Green Technologies and Business Practices: An It Approach*. Information Science Reference.

Potvin-Bernal, J. 2020. "Nudging Eco-Driving Behaviour Using Motive Substitution."

Ramayah, T., Jantan, M., and Ismail, N. 2003. "Impact of Intrinsic and Extrinsic Motivation on Internet Usage in Malaysia," *The 12th International Conference on Management of Technology*, pp. 13-15.

Steg, L., and Vlek, C. 2009. "Encouraging Pro-Environmental Behaviour: An Integrative Review and Research Agenda," *Journal of environmental psychology* (29:3), pp. 309-317.

Sundaram, S., Schwarz, A., Jones, E., and Chin, W. W. 2007. "Technology Use on the Front Line: How Information Technology Enhances Individual Performance," *Journal of the Academy of Marketing Science* (35:1), pp. 101-112.

Taylor, S., and Todd, P. A. 1995. "Understanding Information Technology Usage: A Test of Competing Models," *Information systems research* (6:2), pp. 144-176.

Teo, T. S., Lim, V. K., and Lai, R. Y. 1999. "Intrinsic and Extrinsic Motivation in Internet Usage," *Omega* (27:1), pp. 25-37.

Underwood, G., Chapman, P., Brocklehurst, N., Underwood, J., and Crundall, D. 2003. "Visual Attention While Driving: Sequences of Eye Fixations Made by Experienced and Novice Drivers," *Ergonomics* (46:6), pp. 629-646.

Van Mierlo, J., Maggetto, G., Van de Burgwal, E., and Gense, R. 2004. "Driving Style and Traffic Measures-Influence on Vehicle Emissions and Fuel Consumption," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering* (218:1), pp. 43-50.

Varnfield, M., Karunanithi, M. K., Särelä, A., Garcia, E., Fairfull, A., Oldenburg, B. F., and Walters, D. L. 2011. "Uptake of a Technology‐Assisted Home‐Care Cardiac Rehabilitation Program," *Medical Journal of Australia* (194), pp. S15-S19.

Venkatesh, V., Morris, M. G., Davis, G. B., and Davis, F. D. 2003. "User Acceptance of Information Technology: Toward a Unified View," *MIS quarterly*), pp. 425-478.

Wei, L., Duan, H., Jia, D., Jin, Y., Chen, S., Liu, L., Liu, J., Sun, X., and Li, J. 2020. "Motor Oil Condition Evaluation Based on on-Board Diagnostic System," *Friction* (8:1), pp. 95-106.

Yang, L., Zhang, S., Wu, Y., Chen, Q., Niu, T., Huang, X., Zhang, S., Zhang, L., Zhou, Y., and Hao, J. 2016. "Evaluating Real-World Co2 and Nox Emissions for Public Transit Buses Using a Remote Wireless on-Board Diagnostic (Obd) Approach," *Environmental pollution* (218), pp. 453-462.

Zhang, S., Zhao, J., and Tan, W. 2008. "Extending Tam for Online Learning Systems: An Intrinsic Motivation Perspective," *Tsinghua science and technology* (13:3), pp. 312-317.

1. <http://www.iea.org/publications/freepublications/publication/co2-emissions-from-fuel-combustion-highlights-2020.html> [↑](#footnote-ref-1)