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Reducing CO2 emission and disrupting car travel habits through personalized feedback

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Summary

This paper presents the results of an experimental field study, in which the effects were studied of personalized travel feedback on car owners' car habits, awareness of the environmental impact of their travel choices, and the intention to switch modes. For a period of six weeks, 349 car owners living in Amsterdam used a smart mobility app that automatically registered all their travel movements. Participants in the experiment group received information about travel distance, time, and CO2 emission. Results show that the feedback did not influence self-reported car habits, intention, and awareness, suggesting that personalized feedback may not be a one-size-fits-all solution to change travel habits.

Keywords: car-sharing, ICT (information and communication technology) research, sustainability, user behavior

1 Introduction

1.1 Reducing CO2 emission by electric shared mobility use

Our planet is heating up. A disbalance in CO2 uptake and emissions due to excessive burning of coal, oil and gas and the cultivation and destruction of natural ecosystems is currently leading to higher temperatures [1]. Research shows that the increasing temperatures will have large negative consequences for human mankind, and that it will seriously affect the livability on earth [2]. Scientists also agree: humans are the dominant cause of the current global warming [3]. To slow down and prevent exceeding temperature rises, it is crucial that we reduce our CO2 emission. The goal is set on carbon neutrality by mid-21st century.

Transport is one of the most polluting sectors regarding CO2 emissions. It accounts for approximately one-fifth of global emissions, with three quarters of emissions coming from road travel [4]. Almost half of the emissions come from internal combustion engine passenger vehicles, such as private cars. As transport demands are still increasing due to a growing global population and an increase in average wealth, private car ownership and CO2 emissions are likely to grow even further. To retain and reduce CO2 emissions by passenger vehicles, action is needed.

Electric shared mobility is seen as one of the solutions for the reduction of CO2 emissions by passenger traffic [5, 6]. Shared mobility is defined as a transportation service in which vehicles are shared between users. This can be either through a private construction, in which a fixed user group shares responsibilities and costs, or via a commercial provider with a vehicle fleet. Electric shared mobility has two environmental advantages over private owned fossil fuel cars. First, electric engines of electric shared cars lead to less CO2 emission per kilometer traveled [7,8]. Second, shared mobility leads to volume reduction in terms of vehicles and distance traveled. Research shows that a shared car can remove up to 23 cars from roads, leading to less cars on the streets [9]. Furthermore, after switching to shared mobility, on average less kilometers by car are traveled [10, 11].

1.2 The importance of behavior in the electric shared mobility transition

The potential CO2 emission reduction due to electric shared mobility can only be realized when electric vehicles are used instead of fossil fuel vehicles. For shared mobility to contribute to the CO2 emission reduction goals, owners of fossil fuel cars are an important target group. Such car owners should leave their car and start using electric shared mobility. This requires a serious behavioral change, as car owners must let go current habits, learn new skills, and create new travel patterns. To move people towards electric shared mobility, insights from behavioral science allow us to identify barriers and promising solutions for the required behavioral change [12, 13, 14].

1.3 Stimulating sustainable travel behavior through personalized feedback

The first step in moving car owners away from their car and towards electric shared vehicles is disrupting current car habits [15, 16]. Behavioral studies show that providing personalized feedback through a device may be an effective way to disrupt (unsustainable) travel habits and stimulate new (sustainable) travel behavior such as electric vehicle use [17]. One of the challenges of changing habits is that habitual behavior occurs automatically and outside the awareness of the actor [18]. When changing habits, people first must become aware of their routine behavior so they can reevaluate and change their behavior [19, 20]. Research shows that awareness may be induced by active self-monitoring, for example through personalized behavioral feedback through external tools [21, 22]. Nowadays, many digital devices with sensitive measuring features exist, offering real-time feedback about physical functions and behavior [17]. Think of a sport watch or an app with a pedometer. Such technology enables accurate self-monitoring, allowing users to reflect on their habits and reconsider their choices. Hence, to detach car owners from their car and move them to electric shared mobility, devices with travel feedback that disrupt car habits may be part of the solution.

1.4 This study: the effect of personalized feedback on travel habits

In this paper, the effects of personalized travel feedback on travel habits and the awareness of travel consequences are presented. Adding on existing research on personalized feedback and travel behavior, this study focused on urban car owners and used a smart mobility app that automatically tracked real-time travel movements. The goal of the study was to gain insight in the effects of personalized travel feedback on car use habits, awareness of the impact of travel choices, and the intention to switch from car to more sustainable modes of transport. Furthermore, opportunities for using personalized feedback to disrupt (unsustainable) travel habits and stimulate new sustainable travel behavior such as electric vehicle use are discussed.

2 Methods

2.1 Participants

Participants were recruited via various online digital channels, including websites and social media channels of the city of Amsterdam and the Amsterdam University of Applied Sciences. Additionally, members of the Amsterdam city panel received an invitation via e-mail to join the study. To participate, it was required to live in Amsterdam, possess a car, and have a smartphone with a working internet connection and free memory for the smart mobility app. In exchange for their participation, participants received twenty euros in the form of a voucher for a large online webshop.

In total, 349 respondents completed both pre- and post-surveys, of which 42 respondents indicated in the post-survey that the number of trips was never correctly registered by the smart mobility app or that they never checked the registrations in the app. For these respondents, our treatment was not properly implemented, therefore they are excluded in the final analysis in this paper. As a result, the final participant sample used in the analyses consisted out of 307 participants. In table 1, the descriptive statistics of the sample are shown.

Table 1: Descriptive statistics of the sample

Variable	**Category**	**Frequency**	**Percentage**
Sex	Male	170	55.4
	Female	137	44.6
Age	21-30 years old	26	8.5
	31-40 years old	54	17.6
	41-50 years old	75	24.4
	51-60 years old	79	25.7
	Older than 61 years old	73	23.8
Education level	Secondary education	24	6.9
	Post-secondary vocational education (MBO)	22	6.3
	Higher professional education (HBO)	117	33.5
	Bachelor	22	6.3
	Master or higher	161	46.1
	Others	3	0.9
Monthly net income	Less than €625	2	0.6
	€625-€1250	6	1.7
	€1251 - €1875	17	4.9
	€1876 – €2500	33	9.5
	€2501 – €3125	50	14.3
	More than €3125	206	59.0
	I’d rather not say	35	10.0

2.2 Study design

In November and December of 2021, during a period of six weeks, participants had a smart mobility app on their smartphone. After installing the app and registering their account, the app automatically registered all travel movements and modality use, based on GPS and specific vehicle information through the Netherlands Vehicle Authority data linked to the vehicle’s license plate.

The first two weeks of the study served as the control phase. In this first phase, all participants received an alternative ‘light’ version of the app in which limited travel information was presented. In this version, the starting- and ending point of the travel and used modality could be seen. This was necessary as participants had to be able to check whether the registration was accurate. If this was not the case, the modality could be manually checked from a drop-down list. In the instruction e-mails sent by the research team, participants were asked to regularly check their trips to see if the registrations about mode use were correct and to manually adjust it if necessary.

Directly after the control phase, the four-week intervention phase followed. For this second phase, participants were randomly assigned to either a control or an experimental group. The control group continued with the control version of the app from the first phase. The participants in the experimental group received a new version of the app with an additional feature; a dashboard with extra personalized trip feedback. Besides the start- and ending point of the trip and modality use, the dashboard showed trip information about travel distance, time, CO2 emission and distance traveled by active modes.

2.3 Measures and variables

Participants were randomly assigned to the control- or experiment group. Group assignment served as the independent variable (control = no feedback, experiment = received feedback). Three dependent variables were used, for which data was collected through a pre- and post-survey. A week before the joint start of the study, all participants received the first online survey. The second, post measurement survey was sent on the last day of the study. To be able to measure the effects of the personalized feedback presented in the app, the same constructs and items were used in both surveys. The items used in the three constructs were all measured through a 5-point Likert scale, ranging from 'totally disagree' to 'totally agree'.

Factor analyses were conducted on the dependent variables that consisted of multiple items, to check whether the statements used to measure these constructs loaded on a single factor as expected. If the factor structure was confirmed, then the factor score was determined as the average of all statement scores. Furthermore, the Cronbach's alpha was examined.

The construct *Habitual car use* represents the strength of people's habitual car usage and consisted out of 6 items. All items started with '*Using the car as a means of transport is something..'*, followed by statements such as '*..I do automatically*' and '*..I do without thinking*'. One factor can be extracted from the six measurement statements in both pre- and post-survey, and the Cronbach's alpha is around 0.9. The factor loading of the second statement ('*..I'd think it's weird if I didn't'*) is slightly low (0.6) and excluding it would slightly increase Cronbach's alpha, it is included in the final factor score calculation as it was theoretically meaningful. The construct *Awareness environmental impact personal travel choices* shows to what extent people are aware of the impact of their travel choices on the environment. Initially this construct was measured through three items, starting with '*As for the impact of my transportation choices on the climate,..'*, followed by the three items '*..I am very aware of it'*, '*..I have a good understanding of it',* and '*..I do worry about it'*. Via a factor analysis, one factor may be extracted from the three statements. However, the factor loading of the third statement is quite low (around 0.4) and only after excluding it the Cronbach's alpha is above 0.7. Therefore, this statement is excluded when calculating the score for this construct. The construct *Intention mode shift* measures the intention to reduce car usage and use other modes instead and was measured through the item '*I plan to leave my own car more often in the near future and use other modes of transport (e.g. (electric) shared vehicles, public transport, cycling, walking) instead*.

2.4 Analyses

Given our mixed design (combining between-subjects design and within-subjects design), in order to explore the impact of travel feedback in terms of changing the aforementioned dependent variables, we applied a two-way repeated measures ANOVA to analyze data.

3 Results: impact of personalized travel feedback

To gain insight in the effects of personalized travel feedback on the intention to shift transport modes, habitual car use and awareness of environmental impact of personal travel choices, average scores of the dependent variables in the pre- and post- survey for both the control group and experiment group were calculated (see Table 2). The intention to shift towards more sustainable modes are almost identical for control and experiment groups in the first survey, while the experiment group slightly increased this intention after the experiment. As for habitual car use, in contrast to our expectation, both control and experiment groups consider using car as a habit to a higher extent after the experiment, although the increase of experiment group is slightly lower than that of control group. Regarding the awareness of the environmental impact of personal travel choices, both groups have relatively high awareness in general and the values remain stable after the experiment. To draw conclusions on these averages, repeated measures ANOVA were performed to examine the statistical significance of the impact of travel feedback on the dependent variables.

Table 2: Average score of constructs

Construct	**Group**	**Pre-survey**	**Post-survey**
Intention mode shift	Control (Without feedback)	2.58	2.57
	Experiment (With feedback)	2.59	2.76
Habitual car use	Control (Without feedback)	2.49	2.70
	Experiment (With feedback)	2.70	2.85
Awareness environmental impact personal travel choices	Control (Without feedback)	4.00	4.05
	Experiment (With feedback)	3.97	3.93

Note. All scores are measured on a 5-point Likert scale, higher scores representing higher intentions, stronger car habits, or higher awareness.

Table 3 presents the results of the repeated measures ANOVA's. We see that for all constructs, there is no significant group difference before the experiment, suggesting that the group assignment is random. The interaction of group (travel feedback yes/no) and time is also non-significant in all cases, indicating that the impact of travel feedback in changing the intention to shift transport modes, habitual car use and awareness of environmental impact of personal travel choices is non-significant. Habitual car use of both groups significantly increase with time, meaning that after the end of the study, participants on average had stronger car habits. Regarding the awareness of the environmental impact of personal travel choices, both groups have relatively high awareness in general and the values remain stable after the experiment.

Table 3: Results of repeated measures ANOVA

Impact	Intention mode shift		Habitual car use		Awareness environmental impact personal travel choices	
	F	p	F	p	F	p
CO2 feedback	0.491	0.484	1.803	0.180	0.625	0.430
Time	0.867	0.352	12.946	0.000*	0.006	0.938
CO2 feedback & Time	1.195	0.275	0.407	0.524	1.118	0.291

* p <.001

4 Conclusion and discussion

The transition from private car use to electric shared mobility is seen as a promising strategy to reduce CO2 emissions by passenger travel. However, to reach this potential, car owners must be willing to disengage from their current car habits and switch to electric shared vehicles. The goal of this study was to gain more insight in the effects of personalized feedback on the willingness of car owners to change their current status quo. The results of this study did not show any differences between the control and experimental group on the strength of car use habits, awareness levels of the environmental impact of personal travel choices, and the intention to use other modes instead of their car. So, for these car owners from Amsterdam, receiving personal information about the time and distance they have traveled (per mode and active) and their CO2 emission did not change their travel habits or raise awareness. These results suggest that travel feedback as presented in the smart mobility app does not move car owners to change their habitual car use.

Various previous studies have suggested that personalized feedback is an effective way to change travel behavior [17]. Looking at these studies, it seems that the effects of personalized feedback depend on the way how and when the information is presented. As Brewer and Stern [23] state, in order for information to reach its maximal transformative potential, it must be easy to understand, trusted, presented in a way that attracts attention and is remembered, and delivered as close as possible – in time and place – to the relevant choice. It is possible that the feedback in our study lacked these requirements. By presenting the users their CO2 emission trip data, one would expect that users would become more aware of the impact of their personal travel choices on the environment and adjust their behavior accordingly to this information. However, this was not the case. The presented CO2 trip data may have been too abstract to create the required awareness and make people reevaluate and alter their travel habits. Research on persuasive technology suggests that instead of only presenting CO2 emission in figures, visual representations of the data (e.g., a growing tree) may be added as it helps the user to understand and process the information [17]. Furthermore, the individual user data may be presented next to data from other users (e.g., through a ranking list). In this way, users can compare their behavior with the behavior of others, making it easier to evaluate whether they are on the right or wrong track with their current travel choices [17].

Besides the abstract CO2 data, the non-results may also have to do with a lack of information about feasible alternatives for people’s current way of traveling. Not providing such information may have had consequences for participants intentions to reconsider their travel choices. If people think that their current way of traveling is the optimal way to do so, chances are small they will reevaluate and reconsider their travel choices. Therefore, providing users with information about the consequences of their current behavior linked to feasible alternatives (such as electric shared mobility) could be a way to induce travel change intentions. Such information could also point out the advantages of the alternative option, targeting different motives, appealing to different user groups. Think of communicating individual advantages such as savings in costs and time, and collective advantages such as the environmental impact.

Alongside the nonsignificant effects of travel feedback on the dependent variables, we did find a significant result of time on the construct that indicated strength of habitual car use. Or in other words, people indicated that they had stronger car habits at the end of the study. A possible reason is that the post-measurement survey was conducted in December, a month with a lower average temperature compared to the baseline period (November), making people use their car more and therefore leading to stronger habits. Furthermore, it is possible that COVID restrictions may have influenced people’s travel behavior and habits, as this study was conducted during the COVID pandemic. To limit the number of infections, the government set various restrictions that got stricter during the study. For example, shops and events had to close earlier, people were advised to work at home, and the use of public transport was discouraged. It is possible that the advice to avoid public transport, moved people towards their car leading to a stronger dependence on their car.

Furthermore, a statistical issue should be taken into account. The dependent variables measured via Likert scales turned out to be not normally distributed, which means that the assumption of parametric methods such as ANOVA were not met. However, existing literature shows that these methods can still be used without arriving at wrong conclusions [28].

In short, although previous research suggests that personalized feedback through technological devices can disrupt unsustainable travel habits – a crucial step in the transition towards electric shared mobility use – our experimental field study shows that such feedback is not a 'one size fits all'- solution. Presenting figures about travel time and distance and CO2 emission seem to be not enough to induce a change in travel habits and awareness. Hence, the form and content of the feedback seems to play a significant role in its effectiveness. For feedback to be effective, studies suggest that it should be presented in such a way that users become aware of the current suboptimal state regarding their travel choices, become motivated to change their travel routines, and know what feasible alternative travel options are available. Future research should determine the exact conditions needed for personalized feedback about current fossil fuel-based travel behavior to be effective in promoting pro-environmental travel behaviors.

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References

[1] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3−32, doi:10.1017/9781009157896.001

[2] IPCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press

[3] IPCC, 2022: Summary for Policymakers. In: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.001

[4] J.J. Romm. Eurostat, European Environment Agency, European Topic Centre on Air and Climate Change http://ec.europa.eu/eurostat/statistics-explained/index.php/ Greenhouse_gas_emission_statistics

[5] Mounce, R., & Nelson, J. D. (2019). On the potential for one-way electric vehicle car-sharing in future mobility systems. *Transportation Research Part A: Policy and Practice*, 120, 17-30.

[6] Chen, T. D., & Kockelman, K. M. (2016). Carsharing's life-cycle impacts on energy use and greenhouse gas emissions. *Transportation Research Part D: Transport and Environment*, 47, 276-284.

[7] Nijland, H., Van Meerkerk, J., & Hoen, A. (2015). Impact of car sharing on mobility and CO2 emissions. *PBL Note*, 1-12.

[8] Greenblatt, J.B., & Saxena, S., (2015). Autonomous taxis could greatly reduce greenhouse-gas emissions of US light-duty vehicles. *Nature Climate Change*, 5, 860-863.

[9] Martin, E., Shaheen, S. A., & Lidicker, J. (2010). Impact of carsharing on household vehicle holdings: Results from North American shared-use vehicle survey. *Transportation Research Record*, 2143(1), 150-158.

[10] Martin, E., & Shaheen, S., (2016). Impacts of car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities. *Transportation Sustainability Research Center*, Berkeley, CA.

[11] Viegas, J., Martinez, L., Crist, P., & Masterson, S. (2016). Shared mobility: innovation for liveable cities. In *International Transport Forum's Corporate Partnership Board* (pp. 1-56).

[12] Oskamp, S. (2000). A sustainable future for humanity? How can psychology help? *American Psychologist,* 55(5), 496–508. http://dx.doi.org/10.1037/0003- 066X.55.5.496

[13] Schaefers, T. (2013). Exploring carsharing usage motives: A hierarchical means-end chain analysis. *Transportation Research Part A: Policy and Practice*, 47, 69-77.

[14] Axsen, J., & Sovacool, B. (2019). The roles of users in electric, shared and automated mobility transitions. *Transportation Research Part D: Transport and Environment*. 71. 1-21. 10.1016/j.trd.2019.02.012.

[15] Bamberg, S. (2013). Changing environmentally harmful behaviors: A stage model of self-regulated behavioral change. Journal of Environmental Psychology, 34, 151-159.

[16] Bamberg, S. (2013). Applying the stage model of self-regulated behavioral change in a car use reduction intervention. *Journal of Environmental Psychology*, 33, 68-75.

[17] Anagnostopoulou, E., Bothos, E., Magoutas, B., Schrammel, J., & Mentzas, G. (2018). Persuasive technologies for sustainable mobility: State of the art and emerging trends. *Sustainability*, 10(7), 2128.

[18] Verplanken, B., & Wood, W. (2006). Interventions to break and create consumer habits. *Journal of Public Policy & Marketing*, 25(1), 90-103.

[19] Fischer, C. (2008). Feedback on household electricity consumption: a tool for saving energy*? Energy Efficiency*, 1, 79–104.

[20] Froehlich, J., Dillahunt, T., Klasnja, P., Mankoff, J., Consolvo, S., Harrison, B., & Landay, J. A. (2009). UbiGreen: investigating a mobile tool for tracking and supporting green transportation habits. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1043-1052.

[21] Kim, J. Y., Lee, K. H., Kim, S. H., Kim, K. H., Kim, J. H., Han, J. S., ... & Bae, W. K. (2013). Needs analysis and development of a tailored mobile message program linked with electronic health records for weight reduction. *International Journal of Medical Informatics*, 82(11), 1123-1132.

[22] Li, I., Dey, A., & Forlizzi, J. (2010). A stage-based model of personal informatics systems. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 557-566.

[23] Brewer, G. D., & Stern, P. C. (2005). Decision Making for the Environment: Social and Behavioral Science Research Priorities. *National Academies Press*. 500 Fifth Street NW, Washington, DC 20001.

[28] Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in Health Sciences Education*, 15, 625-632.

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