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Corresponding Author: Dr. Florian Lange,

Corresponding Author's Institution: KU Leuven

First Author: Florian Lange

Order of Authors: Florian Lange; Alexander Steinke; Siegfried Dewitte

Abstract: To address the limitations of self-report measures, we developed the Pro-Environmental Behavior Task (PEBT) as a computerized paradigm for the assessment of actual pro-environmental behavior under controlled laboratory conditions. On each PEBT trial, participants can either choose the faster car option, which causes a series of lights to be illuminated, or they can save the associated energy by choosing the bicycle option at the expense of spending more time in the laboratory. In two pre-registered studies (both N = 120), we showed that the proportion of environmentally friendly PEBT choices is a valid and reliable measure of pro-environmental behavior. PEBT choices were consistent across trials, correlated to conceptually relevant variables, and sensitive to conceptually relevant manipulations. These effects were replicable and independent of the labelling of PEBT options. Our findings highlight the psychometric quality and utility of the PEBT as a paradigm that can open new avenues for research on pro-environmental behavior.

Acknowledgements

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Leuven, 17 February 2018

Dear Dr. Kaiser,

Thank you very much for your positive response to our submission *The Pro-Environmental Behavior Task: A laboratory measure of actual pro-environmental behavior*. We are looking forward to seeing the manuscript published in the *Journal of Environmental Psychology*.

Thank you as well for spotting those two inconsistencies in our report. We changed them accordingly and uploaded a revised version of our manuscript. In addition, we have changed the status of our projects and registrations in the Open Science Framework to “public” and changed the links in the manuscript accordingly. During the review process, our material provided there could be accessed via a private link, now they are accessible to everyone. With regard to the registrations, the status change needs 48 hours to be completed and the new links will only start working after this interval. We will make sure to carefully check the links when reviewing the proofs. Finally, as suggested, we now present our appendices as Supplementary Materials. We uploaded our Supplementary Materials as "Supplementary Interactive Plot data", because we did not find a more appropriate item category in the online submission system. Please let us know if we should change this in any way to facilitate the production process.

Sincerely,

Florian Lange, Alexander Steinke, and Siegfried Dewitte

Florian Lange | BEE – Behavioral Engineering Research Group | KU Leuven | Naamsestraat 69 | 3000 Leuven | Belgium | florian.lange@kuleuven.be

Response to the Reviewers

Editor's comments

I, as well, appreciate the meticulous revision and concur with the reviewers' general positive impression of your paper. Nevertheless, I still have two minor details that need amendment. (1) With the change from standard errors to confidence intervals in Figures 3, A.2 and B.1 the term "error bars" in the figure captions is better changed to "vertical bars". (2) And please drop "methodological" as a qualifier of "practices" in Footnote 1 as it is misleading. Finally, please do not forget to prepare your appendices to be presented as supplementary materials with the final version of your report.

Response

Thank you for spotting those two inconsistencies in our report. We changed them accordingly and uploaded a revised version of our manuscript. As suggested, we now present our appendices as Supplementary Materials. We uploaded our Supplementary Materials as "Supplementary Interactive Plot data", because we did not find a more appropriate item category in the online submission system. Please let us know if we should change this in any way to facilitate the production process.

Highlights

- This paper introduces the Pro-Environmental Behavior Task (PEBT).
- PEBT choices lead to actual consequences for the individual and for the environment.
- Two pre-registered studies support the validity and reliability of the PEBT.
- PEBT choices are correlated to conceptually relevant self-report measures.
- PEBT choices are sensitive to the individual and environmental costs of the behavior.

The Pro-Environmental Behavior Task: A laboratory measure of actual pro-environmental behavior

Florian Lange[1], Alexander Steinke[2], Siegfried Dewitte[1]

[1]Behavioral Engineering Research Group, KU Leuven, Leuven, Belgium

[2]Department of Neurology, Hannover Medical School, Hannover, Germany

Correspondence:

Florian Lange

BEE – Behavioral Engineering Research Group

KU Leuven

Naamsestraat 69

3000 Leuven

Belgium

florian.lange@kuleuven.be

The Pro-Environmental Behavior Task: A laboratory measure of actual pro-environmental behavior

Abstract

To address the limitations of self-report measures, we developed the Pro-Environmental Behavior Task (PEBT) as a computerized paradigm for the assessment of actual pro-environmental behavior under controlled laboratory conditions. On each PEBT trial, participants can either choose the faster car option, which causes a series of lights to be illuminated, or they can save the associated energy by choosing the bicycle option at the expense of spending more time in the laboratory. In two pre-registered studies (both $N = 120$), we showed that the proportion of environmentally friendly PEBT choices is a valid and reliable measure of pro-environmental behavior. PEBT choices were consistent across trials, correlated to conceptually relevant variables, and sensitive to conceptually relevant manipulations. These effects were replicable and independent of the labelling of PEBT options. Our findings highlight the psychometric quality and utility of the PEBT as a paradigm that can open new avenues for research on pro-environmental behavior.

Keywords: pro-environmental behavior; behavioral tasks; actual behavior; measuring behavior; interventions; transportation

The Pro-Environmental Behavior Task: A laboratory measure of actual pro-environmental behavior

1. Introduction

The science of pro-environmental behavior is, to a large extent, a science of self-report measures (Steg & Vlek, 2009). More than 80% of recent pro-environmental behavior studies in the *Journal of Environmental Psychology* (published in 2015 and 2016) relied exclusively on participants' subjective accounts of their behavior or its proposed psychological antecedents (e.g., intentions or attitudes)[1]. The disadvantages of this methodological approach are routinely discussed as a limitation of these studies (e.g., in Bissing-Olson, Fielding, & Iyer, 2016; Buchanan & Russo, 2015; Chen, 2015; Collado, Evans, Corralza, & Sorrel, 2015; De Leeuw, Valois, Ajzen, & Schmidt, 2015; Jugert et al., 2016; Lavergne & Pelletier, 2015; Lind, Nordfjærn, Jørgensen, & Rundmo, 2015; Unanue, Vignoles, Dittmar, & Vansteenkiste, 2016; Verplanken & Roy, 2016; Visschers, Wickli, & Siegrist, 2016). Self-reports of behavior may be distorted by social desirability (but see Milfont, 2009), consistency biases, participants' inability to accurately recall the behavior in question, and individual differences in the interpretation of items (Gifford, 2014). As a result, a large portion of the variance in actual pro-environmental behavior cannot be accounted for by self-report measures of pro-environmental behavior (Kormos & Gifford, 2014).

In addition to these validity concerns, the focus on self-report measures may also restrict the research questions and designs used in the study of pro-environmental behavior. Only a single one (i.e., Verplanken & Roy, 2016) of the 26 recent *Journal of Environmental Psychology* studies assessing pro-environmental behavior exclusively via self-report employed an experimental design to investigate the effectiveness of an intervention to promote pro-environmental behavior[2]. The overwhelming majority of these studies examined the correlative relationship between self-reported behavior and other (mostly self-reported)

variables. This approach might reveal important insights into the antecedents of pro-environmental behavior as well as implications for the design of interventions. However, the associated inability to establish cause-effect relationships in combination with the incongruity between reported and actual behavior severely limits the conclusiveness and usefulness of correlational self-report studies (cf. Bamberg & Möser, 2007).

Studies investigating the effect of an intervention on directly observed pro-environmental behavior may seem an ideal solution to overcome these limitations. In 2015 and 2016, eleven *Journal of Environmental Psychology* studies reported data obtained from observing actual pro-environmental behavior or a proxy thereof (e.g., the amount of water saved/waste recycled). Ten of these studies employed an experimental or quasi-experimental design. They demonstrated, for example, how social norm manipulations affect everyday pro-environmental behavior in the domains of energy conservation (Dwyer, Maki, & Rothman, 2015), waste reduction (Hamann, Reese, Seewald, & Loeschinger, 2015), and towel reuse (Terrier & Marfaing, 2015). However, studies of actual pro-environmental behavior in the field come along with their own set of critical methodological limitations. Most importantly, in many cases, it is not possible to randomly assign and reliably track individual participants (see, e.g., Bergquist & Nilsson, 2016). As a corollary, some individuals may contribute more than one observation to the data set (see, e.g., Murtagh, Gatersleben, Cowen, & Uzzell, 2015) and relating the effectiveness of the intervention to individual difference data is hardly feasible (see, e.g., Hamann et al., 2015). Hence, despite the appeal of studying actual pro-environmental behavior in the field, internal validity concerns often undermine the utility of these designs in evaluating interventions.

The reliance on correlational self-report studies and, to a lesser extent, quasi-experimental field research likely obstructs progress towards a better understanding of the causal mechanisms underlying pro-environmental behavior. We propose that the study of pro-

environmental behavior would greatly benefit from an increased focus on the investigation of actual pro-environmental behavior under controlled laboratory conditions. Such a methodological approach would allow examining the determinants of pro-environmental behavior without suffering from the limitations associated with questionnaire studies or field research. Unlike self-report studies, it would facilitate the adoption of experimental designs while not being vulnerable to reporting biases. Unlike field studies, it would give the experimenter complete control over participant assignment as well as access to individual-level background data. In addition, behavioral investigations in the laboratory open new avenues in the study of pro-environmental behavior by allowing for, for example, parametric manipulations or complex multifactorial designs. Despite these advantages, analyses of pro-environmental behavior in the laboratory are rare. Only two of the *Journal of Environmental Psychology* studies from 2015 and 2016 (i.e., Demarque, Charalambides, Hilton, & Waroquier, 2015; Murtagh et al., 2015) involved a laboratory assessment of actual pro-environmental behavior.

We argue that one of the reasons for this low number of laboratory studies might be the lack of an established, valid, and reliable paradigm for the assessment of pro-environmental behavior in the lab. Most of the laboratory measures used in previous studies seem to have been developed for the particular research question at hand and we are not aware of any standardized paradigm that has been used in more than one study. In addition, previously used measures tend to rely on single-trial data. For example, participants in the study by Murtagh et al. (2015) could turn off or leave on the laboratory lights while individuals participating in the study by Huffman, Van Der Werff, Henning, & Watrous-Rodriguez (2014) could recycle or not when disposing of their study materials. The respective single-trial measures of pro-environmental behavior are unlikely to be reliable (Churchill, 1979). Moreover, their relationship to other pro-environmental behavior measures remains

unclear. Due to the unknown psychometric properties of laboratory measures of actual pro-environmental behavior, it is not very surprising that many environmental psychologists resort to self-report measures.

To address these limitations of previous approaches to the measurement of pro-environmental behavior, we developed a multiple-trial computerized procedure for the assessment of actual pro-environmental behavior under controlled laboratory conditions. The Pro-Environmental Behavior Task (PEBT) involves a series of choices between two response options. On each choice trial, participants have to decide whether they want to use the car or the bicycle for a particular trip. Participants directly experience two different types of consequences that are contingent on their choice. First, following their choice, participants have to endure a waiting period before they can choose a mode of transportation for the next trip. In general, the waiting period associated with choosing the bicycle option is longer than the waiting period associated with choosing the car option. Second, following a choice of the car option, an array of USB-powered lights is illuminated for the duration of the trip. Before making their choice, participants are explicitly informed about the waiting periods associated with the two options as well as about number of lights to be illuminated by choosing the car option. They are also informed about the estimated amount of carbon dioxide (CO_2) emitted by illuminating the lights. Hence, participants can choose between the car option associated with shorter waiting times and negative environmental consequences (i.e., the waste of resources/emission of CO_2 caused by the illumination of the lights) on the one hand, and the bicycle option associated with longer waiting times but no environmental consequences on the other hand. We will refer to the bicycle option as the environmentally friendly option and to the car option as the environmentally unfriendly option in the following.

The corresponding measure of actual pro-environmental behavior (i.e., the proportion of environmentally friendly choices) has a number of important advantages. First, it is based

on participants' responses across multiple trials, rendering the aggregate measure more reliable than single-trial measures of actual pro-environmental behavior. Second, the PEBT attaches a cost (i.e., longer waiting times) to choosing the environmentally friendly option. It thus involves a conflict between individual and environmental consequences, which is characteristic of many environmentally significant decisions in everyday life (Gifford, 2011; Steg, 2015). Third, unlike previous approaches to capture the behavioral trade-off between individual and environmental consequences (e.g., Pichert & Katsikopoulos, 2008; van Vugt, Mertens, & van Lange, 1995), consequences are not hypothetical in the PEBT. Choosing the environmentally friendly option on the PEBT directly results in an actual increase in waiting time and an actual reduction of CO_2 emissions. As a consequence, behavior on the PEBT is not a proxy for environmentally significant behavior, it *is* environmentally significant behavior (as defined by Stern, 2000).

In the following, we describe two pre-registered studies that we designed to examine the validity of the PEBT. Both studies tested the same set of hypotheses with the second study being a conceptual replication of our first study. Our studies focused on the proportion of environmentally friendly choices on the PEBT as a proposed measure of pro-environmental behavior. We required this measure to vary as a function of two different types of consequences in order for it to be considered a valid reflection of an individual's propensity to behave pro-environmentally. First, behavior on the PEBT should depend on the individual costs associated with the two transportation options. Having a set of pro-environmental behaviors that is ordered transitively according to the costs or difficulty of these behaviors allows measuring an individual's propensity to engage in pro-environmental behavior (Kaiser, Byrka, & Hartig, 2010). To manipulate the individual costs of pro-environmental behavior, we varied the waiting time difference between the environmentally friendly option and the environmentally unfriendly option on the PEBT. A systematic effect of this variable on PEBT

choices would also rule out the possibility that behavior on the PEBT is entirely driven by social desirability. If participants exclusively strived to display socially approved (i.e., pro-environmental) behavior, they should select the environmentally friendly PEBT option independent of whether it is associated with a delay of 15 seconds or a delay of 20 seconds.

Hypothesis 1: The proportion of environmentally friendly choices decreases with increasing waiting time differences between the environmentally friendly option and the environmentally unfriendly option.

A second type of consequence that should affect behavior on the PEBT are the locally produced environmental costs associated with the two PEBT options. When a behavior is performed because of its impact on the environment, the likelihood of its occurrence can be expected to increase when it produces more severe environmental costs. On the PEBT, the environmental costs of choosing the environmentally unfriendly option are rather low and it is possible that participants do not take into account the small amounts of CO_2 emissions produced by choosing that option. An effect of the amount of CO_2 emissions associated with PEBT choices would, however, indicate that behavior on the PEBT is at least partly driven by individuals' propensity to reduce the negative environmental consequences of their behavior. To manipulate the environmental costs of pro-environmental behavior, we varied the number of lights to be illuminated (and thus the amount of CO_2 to be emitted) by choosing the environmentally unfriendly option on the PEBT. A systematic effect of this variable on PEBT choices would indicate that participants are not insensitive to the environmental costs produced by the lamps, and that behavior on the PEBT is sensitive to changes in the local task context. This sensitivity is also a critical prerequisite for using the PEBT in future studies to evaluate the impact of contextual interventions on pro-environmental behavior.

Hypothesis 2: The proportion of environmentally friendly choices increases with increasing CO_2 emissions (operationalized via the number of illuminated lights) associated with the environmentally unfriendly option.

In addition, if the proportion of environmentally friendly choices on the PEBT is a valid measure of pro-environmental behavior, it should correlate with established measures of pro-environmental behavior as well as with measures that are known to be closely related to pro-environmental behavior. We selected five measures that we hypothesized to be positively related to the proportion of environmentally friendly choices and one measure that we hypothesized to be negatively related to the proportion of environmentally friendly choices.

Hypothesis 3: The proportion of environmentally friendly choices is positively related to self-reported pro-environmental behavior, environmental attitudes, environmental concern, environmental identity, and biospheric value orientations, but negatively related to egoistic value orientation.

To shed further light on the psychometric properties of the PEBT, we also calculated a series of reliability indices (not pre-registered). In combination, these analyses should allow examining whether the proportion of environmentally friendly choices on the PEBT qualifies as a laboratory measure of pro-environmental behavior.

2. Methods

We will first present a comprehensive account of a first validation study that we designed to test the three hypotheses outlined above. The registration of this study including all planned confirmatory analyses can be found at https://osf.io/pkztu/. We will then briefly discuss the results of a replication study (https://osf.io/x2qh3/). A more detailed description of this replication study can be found in the Supplementary Materials. The Supplementary Materials also contain the results of exploratory analyses that we ran to further characterize the properties of the PEBT. All data from our two studies can be found at https://osf.io/tcnza/.

We confirm that, for both studies, we have reported all conditions and data exclusions, as well as how we determined our sample sizes. We have also reported all measures of relevance for the pre-registered confirmatory analyses of our hypotheses. Data from non-registered measures that have been included for exploratory reasons are included in the data set mentioned above.

2.1 Sample size determination and participants

The correlational test of Hypothesis 3 is likely to be less powerful than the within-subject comparisons associated with testing Hypothesis 1 and Hypothesis 2. As a consequence, we based our sample-size calculation on assumptions regarding Hypothesis 3. The study most closely related to the present one examined the correlation between pro-environmental travel mode choices in hypothetical scenarios and environmental concern (van Vugt et al., 1995). They found a correlation as large as $r = .66$. Correlations between environmental attitude and pro-environmental behavior typically vary around $r = .40$ (Bamberg & Möser, 2007; Kraus, 1995). We wanted to be able to also detect slightly smaller correlations of medium size ($r = .30$) with good statistical power (95%, given $\alpha = .05$, one-tailed test). At the same time, we wanted to still have sufficient statistical power (80%) at a corrected alpha-level of $\alpha = .0083$ (.05 divided by 6, i.e., the number of examined correlations). Power analysis (G*Power 3.1.9.2, Faul, Erdfelder, Lang & Buchner, 2007) renders $N = 115$ participants for the first set of parameters and $N = 112$ participants for the second set of parameters. We rounded the larger of these two values to the next multiple of six to arrive at a target sample size (i.e., $N = 120$) that allows for a fully counterbalanced order of our experimental conditions.

When advertising the study to participants that are enlisted in the faculty's subject pool, we offered 120 testing slots and attempted to find participants for these slots. Participants were tested in groups of up to six people. Because some participants cancelled

their participation or did not show up for their session, we did not reach the target sample size with these first 120 testing slots (107 participants were tested during this first wave). As pre-registered, we opened new testing slots until the target sample size of $N = 120$ was reached. Due to overbooking for the final testing slots, data were collected from two additional participants. Before running any analyses, we decided to exclude these data to avoid deviations from the pre-registered protocol and to guarantee that our design is fully counterbalanced. No further data were excluded.

Of the final sample, 61 participants were female (58 male, one preferred not to say). Participants' age ranged from 16 to 62 yrs ($M = 24.58$ yrs, $SD = 6.77$ yrs). Ninety percent of the participants were students and 73% of them named Dutch as their native language. Seventy-four percent indicated to have a driver's license, 32% had a car, and 96% had a bicycle. Participants received a payment 12 € for a study that, in most cases, lasted between 40 and 60 minutes. The study was approved by the local ethics committee (G- 2016 12 694).

2.2 Self-report measures

Self-report measures were designed and presented using the Qualtrics software. All participants completed the measures in the same fixed order. They first responded to the five self-report measures involved in the pre-registered correlation analysis of Hypothesis 3.

As a self-report measure of pro-environmental attitudes, we administered the brief version of the Environmental Attitudes Inventory (EAI-24, Milfont & Duckitt, 2010). Participants responded on a 7-point Likert scale (ranging from strongly disagree to strongly agree). The EAI-24 can be broken down into twelve first-order factors (e.g., enjoyment of nature, support for interventionist conservation policies, and confidence in science and technology), each of which is assessed by two items. For the purpose of our study, we computed the average value across all 24 items to assess a single second-order factor

reflecting generalized environmental attitudes (Milfont & Duckitt, 2010). Reliability (Cronbach's alpha) of this measure was $\alpha = .87$ (replication study: $\alpha = .79$).

To assess self-reported pro-environmental behavior, we asked participants to report how frequently they engaged in twelve behaviors of environmental significance (e.g., recycling newspapers, conserving gasoline, donating to environmental groups) during the past year. The same items have been used before and are described in detail by Schultz and colleagues (2005). Participants responded on a 5-point scale (never, rarely, sometimes, often, very often). They were instructed to indicate "not applicable" when they thought that there was no opportunity to perform the behavior during the past year. We calculated the average item score across all behaviors whose frequency had been rated. Reliability of this measure was $\alpha = .87$ (replication study: $\alpha = .77$).

Participants also responded to the 15 items of the revised New Environmental Paradigm Scale (NEP, Dunlap et al., 2000). These items relate to five postulated facets of environmental concern (assessing participants' beliefs about limits to growth, anthropocentrism, the fragility of nature's balance, exemptionalism, and the possibility of an eco-crisis) and have been shown to form a unidimensional scale. Participants responded on a 5-point Likert scale (ranging from strongly disagree to strongly agree). We computed the average item score across all items to obtain a self-report measure of environmental concern. Reliability of this measure was $\alpha = .81$ (replication study: $\alpha = .75$).

We further administered a self-report instrument to assess values that have been proposed to be related to pro-environmental behavior (de Groot and Steg, 2010). Participants were asked to rate the importance of 13 values (e.g., wealth, social justice, unity with nature) for their lives on a 9-point scale (ranging from -1 = opposed to the value, 0 = not at all important to 7 = of supreme importance). The value instrument is composed of three scales assessing egoistic, altruistic, and biospheric value orientations, respectively. We computed

average item scores for two of these scales (egoistic and biospheric value orientations) for our pre-registered analyses. Reliability was α = .77 (replication study: α = .71) for the egoistic value orientations scale and α = .90 (replication study: α = .84) for the biospheric value orientations scale.

Next, participants were asked to respond to the three items forming the environmental self-identity scale reported by van der Werff, Steg, and Keizer (2013; e.g., "I am the type of person who acts environmentally friendly"). They responded on a 7-point Likert scale (ranging from strongly disagree to strongly agree). We computed the average item score across all items to obtain a self-report measure of environmental identity. Reliability of this measure was α = .93 (replication study: α = .85).

After having completed these five scales, participants responded to a number of additional questions that were not relevant for the confirmatory analyses pre-registered for this study. The questionnaire ended with some questions asking participants for demographic information (see section Sample size determination and participants for results).

2.3 The Pro-Environmental Behavior Task (PEBT)

After the self-report measures, participants completed 72 trials on the PEBT. The PEBT was designed and run using OpenSesame version 3.1.4 (Mathôt, Schreij, & Theeuwes, 2012). To allow for an experimental manipulation of energy consumption and associated CO_2 emissions, we connected the computer running the software to three self-powered USB hubs, each of them being connected to four USB-powered lights via a USB 2.0 cable. BlinkStick squares embedded in a cube-shaped enclosure were used as lights (https://www.blinkstick.com/). These squares consist of eight individually addressable light-emitting diodes (LEDs) that can be controlled using Python code. We created Python inline scripts for OpenSesame to turn the BlinkStick squares on and off as required during the trial sequence of the PEBT. The RGB values for the LEDs were set to (100, 100, 100) in order for

the BlickStick squares to emit white light. Each light measured approximately 3 cm × 3 cm × 3 cm. Each of the sets of four lights connected to one of the USB hubs was mounted on a separate wooden plate that was placed under the desk of the participant. This location was chosen to limit distracting effects of the lights during the execution of the task. A photograph of the apparatus can be found in the Supplementary Materials.

Each trial on the PEBT consisted of the presentation of a choice display and a waiting period, whose properties were contingent on participants' responses to the choice display (see Figure 1 & 2). The choice display presented participants with two travel options (i.e., the car and the bicycle). Participants were asked which of these means of transportation they would like to use for the upcoming trip. They received explicit instructions about the travel times associated with the two options as well as about the travel-time difference between the options. In addition, they were informed about the number of lights to be illuminated and the amount of CO_2 to be emitted in the event that they choose the car option. According to the manufacturer, each of the lights uses about 2.4 Watt. For the ease of communication within the experiment, we rounded this value, assumed that a kwh of electricity emits 300 g of CO_2 and thus that powering one of the lights for one hour produces about 750 mg of CO_2. Choice displays remained on screen until participants mouse-clicked on one of the two travel option.

Depending on participants' choice, the length of the waiting period as well as the number of lights turned on during this period varied according to the values that were given on the choice display. During the waiting period, a waiting time display was presented that informed participants about the current state of the lights (see Figure 1 & 2). After the respective waiting time had elapsed, the waiting time display disappeared and the next choice display was presented.

Participants completed three blocks of 24 PEBT trials. Across blocks, we varied the number of lights to be illuminated (four vs. eight vs. twelve). Block order was

counterbalanced across participants. In addition to the information provided on every choice display, participants were informed about the number of lights that would be turned on by choosing the car option (and the associated CO_2 amount) at the beginning of each block. To facilitate the interpretation and comparison of these different CO_2 conditions, we also mentioned whether choosing the car consumed a relatively large (12 lights, 9000 mg/h CO_2), medium (8 lights, 6000 mg/h CO_2), or small amount of energy (4 lights, 3000 mg/h CO_2) in the upcoming block of trials.

In addition to the block-wise manipulation of CO_2 emissions, we also manipulated the difference in waiting time between the environmentally unfriendly option and the environmentally friendly option on a trial-by-trial basis. Waiting times associated with choosing the car were either 5, 10, 15, or 20 seconds. Waiting times associated with choosing the bicycle were either 0, 5, 10, 15, 20, or 30 seconds longer than waiting times associated with choosing the car. Each of the resulting 24 waiting time combinations was presented once during each of the three blocks of PEBT trials. Hence, across all 72 trials of the PEBT, there were 12 trials for each of the six waiting time difference conditions (0 s, 5 s, 10 s, 15 s, 20 s, 30 s). The order of trials within each of the three blocks was randomized for each participant.

At the beginning of the task, participants received the following general instructions:

> In our computer task, you will have to choose a mode of transportation (the car or the bike) for a number of different trips. After you have decided for a mode of transportation, you will have to wait until the trip is completed. When the trip is completed, you will have to choose a mode of transportation for the next trip. In most cases, taking the bike will take more time than taking the car. Depending on the nature of the trip, the travel time difference between the two options will be smaller or larger. Also, just like in everyday life, taking the car will consume some energy and produce CO_2 emissions. If you choose the car option, a number of lights will be turned on for

the duration of your trip. The lights are located under your table. Each of these lights produces about 750mg/h of CO_2. Click OK to see an example.

Participants then saw an example involving the choice of the car option to learn how the lights worked. In this example, eight lights were turned on for a trip duration of 15 seconds and participants saw the standard waiting period display (see Figure 1) with the added instruction to look under the table to see the illuminated lights. Following this demonstration, they were asked to notify the experimenter in case of any further questions. Before beginning with the task, participants were informed that "[t]here will be three separate blocks, each consisting of a series of trips." Between blocks, participants were allowed to take a break for as long as they wished. The OpenSesame script of the task can be found at https://osf.io/tcnza/.

2.4 Procedure

After having provided informed consent, participants completed the self-report measures in the order described above. They then notified the experimenter who set up the PEBT. Following the completion of the 72 PEBT trials, participants were thanked and seen off. All materials were administered in English language.

Participants were tested in groups of up to six people. Each participant was assigned a seat in a partially enclosed cubicle and then completed the study in private on a personal computer. It was ascertained that participants did not have their phones or any other potentially distracting materials with them in the cubicle. There always was an empty cubicle between two participants which ensured that no participant was able to see whether the lights belonging to another participant were turned on or off.

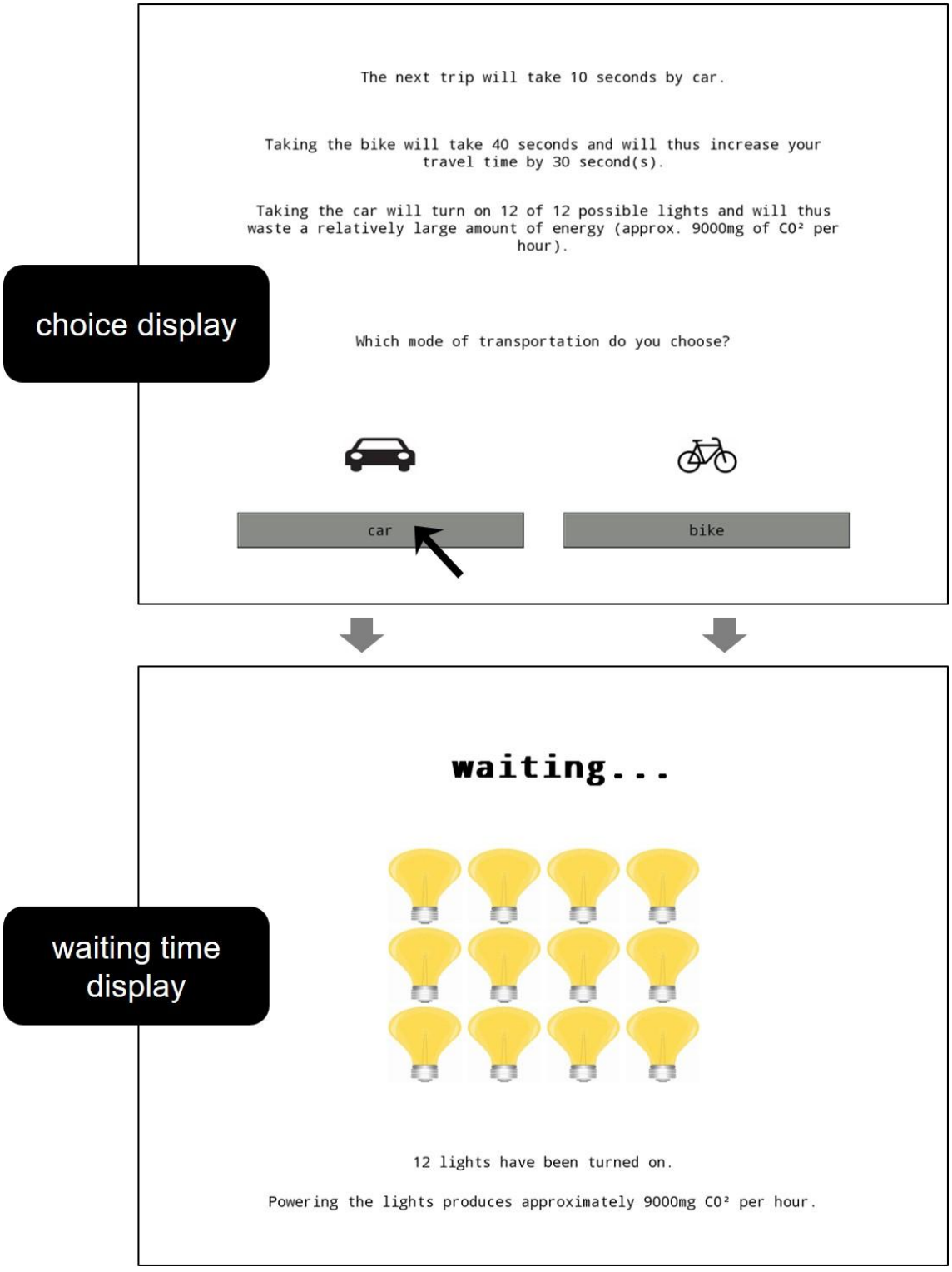

Figure 1. Example of a trial on which the participant chooses the environmentally unfriendly car option. The waiting time display is presented for the duration indicated on the choice display. During the presentation of the waiting time display, a corresponding number of lights under the desk are turned on.

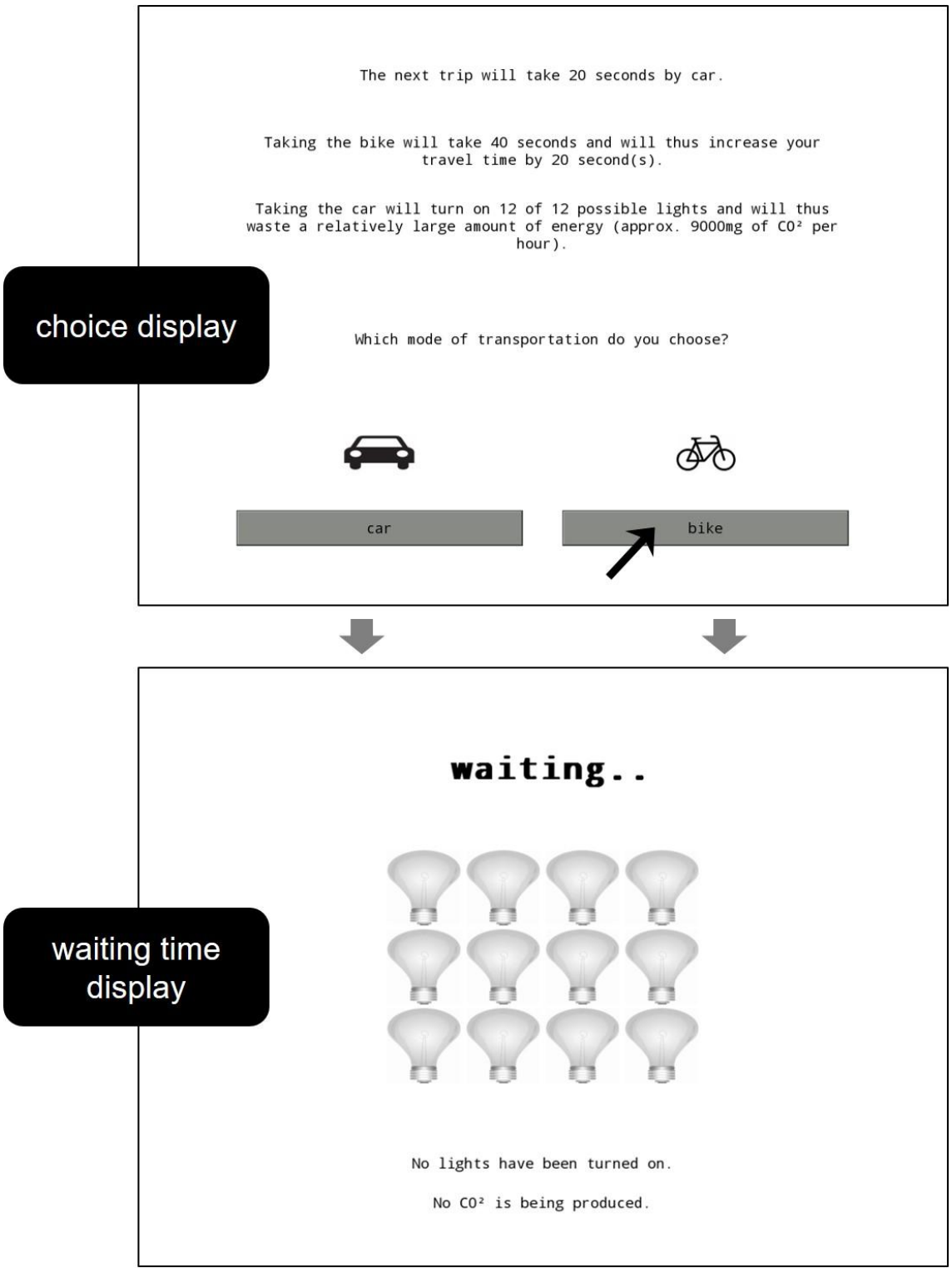

Figure 2. Example of a trial on which the participant chooses the environmentally friendly bicycle option. The waiting time display is presented for the duration indicated on the choice display. During the presentation of the waiting time display, the lights under the desk are turned off.

2.5 Analyses

To test Hypothesis 1, we submitted the proportion of environmentally friendly choices to a repeated-measures analysis of variance (ANOVA) with the within-subject factor waiting time difference (WTD; 0 s, 5 s, 10 s, 15 s, 20 s, 30 s). We pre-registered two criteria to be met by our data in order to consider them as support for Hypothesis 1: a) a significant effect of waiting time difference on the proportion of environmentally friendly choices ($\alpha = .05$, as revealed by the ANOVA) and b) a monotonic decrease of the proportion of environmentally friendly choices from small to large WTDs (as revealed by visual data inspection).

To test Hypothesis 2, we submitted the proportion of environmentally friendly choices to a repeated-measures analysis of variance (ANOVA) with the within-subject factor CO_2 condition (3000 mg/h, 6000 mg/h, 9000 mg/h). A significant effect of CO_2 condition on the proportion of environmentally friendly choices ($\alpha = .05$) in combination with a monotonic increase of the proportion of environmentally friendly choices from small to large amounts of CO_2 emissions (as revealed by visual data inspection) was interpreted as evidence for Hypothesis 2.

To test Hypothesis 3, Pearson correlation coefficients were calculated for the associations between the overall proportion of environmentally friendly choices and average item scores on the EAI-24, the self-report measure of environmental behavior, the NEP, the egoistic and biospheric scale of the value instrument, and the environmental self-identity scale. For these analyses, the level of significance was set to .05/6 = .0083 to adjust for the number of examined correlations. One-sided tests were used. A significant negative correlation between the overall proportion of environmentally friendly choices and the egoistic value orientation scale was interpreted as evidence for Hypothesis 3. For the other five measures, positive correlations with the overall proportion of environmentally friendly choices were interpreted as evidence for Hypothesis 3.

3. Results

The overall proportion of environmentally friendly choices ranged from 17% to 100% (M = 67% , SD = 24%). For the sake of interpretability, we describe and display untransformed environmentally friendly choices. As pre-registered, all analyses were run on arcsine transformed choice data (M = 1.01, SD = 0.32). To exclude the possibility that our results depend on this potentially controversial choice (see e.g., Warton & Hui, 2011), we present analyses of untransformed data alongside the primary analyses of transformed data.

3.1 Hypothesis 1

The difference in waiting times associated with the two travel options exerted a strong effect on the proportion of environmentally friendly choices, $F(5, 595) = 203.42$, $p < .001$, $\eta_p^2 = .63$ (untransformed data: $F(5, 595) = 189.45$, $p < .001$, $\eta_p^2 = .61$). Greenhouse-Geisser correction (not pre-registered) did not qualitatively affect the results (i.e., p remained smaller than .001). Inspection of Figure 3 confirms Hypothesis 1 in revealing a monotonic decrease of the proportion of environmentally friendly choices from small to large WTDs.

3.2 Hypothesis 2

The proportion of environmentally friendly choices was also significantly affected by the amount of CO_2 emissions (operationalized via the number of illuminated lights) associated with the car option, $F(2, 238) = 18.47$, $p < .001$, $\eta_p^2 = .13$ (untransformed data: $F(2, 238) = 18.40$, $p < .001$, $\eta_p^2 = .13$). Greenhouse-Geisser correction (not pre-registered) did not qualitatively affect the results (i.e., p remained smaller than .001). Inspection of Figure 3 confirms Hypothesis 2 in revealing a monotonic increase of the proportion of environmentally friendly choices from small to large amounts of CO_2 emissions.

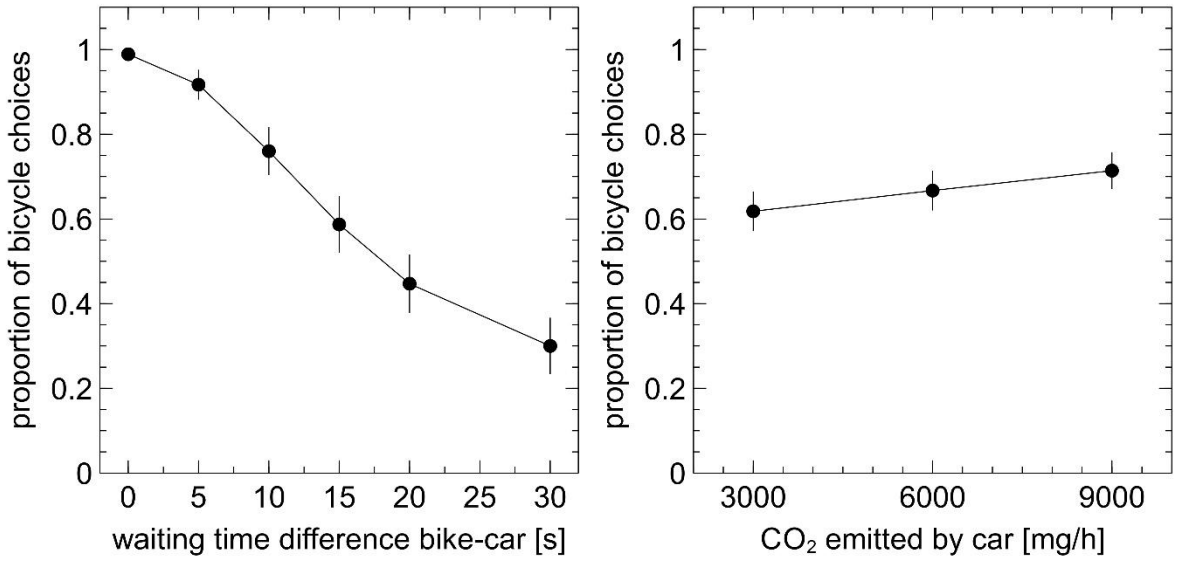

Figure 3. Proportion of environmentally friendly bicycle choices as a function of the waiting time difference between the environmentally friendly and environmentally unfriendly option (left) and as a function of the amount of CO_2 emissions (operationalized via the number of illuminated lights) associated with the environmentally unfriendly option (right). Vertical bars indicate 95% confidence intervals.

3.3 Hypothesis 3

The proportion of environmentally friendly choices was positively related to self-report measures of environmental attitudes, environmental concern, environmental identity, ecological behavior, and biospheric value orientation while being negatively related to egoistic value orientations. With the exception of the relationship to biospheric value orientation, $p = .019$ (one-tailed correlation), all correlations were significant at the corrected significance level of $\alpha = .0083$, all $p < .001$ (see Table 1). Visual data inspection (see Supplementary Materials) indicated that data for some of the variables included in our correlation analyses might not be normally distributed. All significant correlations remain significant when tested non-parametrically (not-preregistered).

3.4 Reliability analysis

Using single-trial data, we computed a Cronbach's alpha of $\alpha = .974$ for the 72 trials of the PEBT. Split-half reliability according to Spearman-Brown was .980. Reliability estimates based on Guttman's lambdas ranged from .960 to .979 ($\lambda_1 = .960$, $\lambda_2 = .979$, $\lambda_3 = .974$, $\lambda_4 = .978$, $\lambda_5 = .966$).

Table 1.

Pearson correlation coefficients for the relationships between the proportion of environmentally friendly (EF) choices on the Pro-Environmental Behavior Task and self-report measures

	Measure	1	2	3	4	5	6	7
1	Proportion of EF choices	-	**.43****	**.39****	**.35****	**.31****	**.20***	**-.30****
2	Environmental attitudes	**.41****	-	.77	.67	.55	.63	-.32
3	Environmental concern	**.40****	.77	-	.47	.36	.49	-.26
4	Environmental identity	**.34****	.67	.47	-	.64	.70	-.03
5	Ecological behavior	**.32****	.55	.36	.64	-	.51	-.03
6	Biospheric value orientation	**.19***	.63	.49	.70	.51	-	.06
7	Egoistic value orientation	**-.31****	-.32	-.26	-.03	-.03	.06	-

Note: Correlations involving arcsine transformed choice data are presented below the diagonal; correlations involving untransformed choice data are presented above the diagonal. Correlations of interest for confirmatory hypothesis testing are highlighted in bold. The correlations between self-report measures were not compared against a significance threshold.

*significant at $p < .05$, one-sided

**significant at the corrected $p < .0083$, one-sided

4. Replication

The purpose of our second validation study was twofold. First, we aimed to replicate the results of our first study to generate further empirical support for the psychometric quality of the PEBT. Second, after having completed their testing session, some individuals

participating in our first study indicated that the specific labels we chose for the environmentally friendly and the environmentally unfriendly option (i.e., "bicycle" and "car") had influenced their behavior on the PEBT. They described, for example, that they always chose the bicycle option because they did not have access to a car in everyday life. The applicability of the PEBT as a paradigm for the study of pro-environmental behavior would be severely limited if participants' behavior in the laboratory were systematically affected by the availability of transportation options outside the laboratory. In order to address this potential limitation, we replaced the labels of the two PEBT options with arbitrary labels in our replication study. Participants in that study chose between two "newly developed" means of transportation that were associated with the same two sets of consequences (shorter waiting time, energy-consuming vs. longer waiting time, not energy-consuming) as the PEBT options used in our first study. Based on a pretest (N = 22) the names for the options were selected from a list of pseudowords to be matched with regard to a number of connotations (overall valence, speed, comfort, environmental friendliness, fuel consumption). The assignment of the selected pseudowords (i.e., "sest" and "dift") to the two sets of consequences was counterbalanced across participants. Hence, behavior on this revised version of the PEBT is unlikely to be affected by the labelling of the two PEBT options. The only factor that systematically differed between the two PEBT options were the individual and environmental consequences associated with them. Replication of the findings from our first study using arbitrary labels would suggest that these findings were driven by the demand to trade off these consequences while completing the PEBT instead of by the labeling of PEBT options. As a corollary, it would support the utility of the PEBT for the study of pro-environmental behavior, even in individuals with restricted access to transportation options in everyday life.

We pre-registered the same three hypotheses, tested according to the same procedure as in our firs study. In addition, we examined whether the strength of the relationships

investigated under Hypotheses 1-3 or the overall proportion of environmentally friendly PEBT choices varied between our two studies. We made no predictions with regard to the existence or direction of possible between-study differences.

Based on the same sample size rationale, stopping rule, and sampling procedure as applied in our first study, we obtained data from $N = 120$ participants. Individuals who participated in the first study were excluded from participation in the replication study. The overall proportion of environmentally friendly choices in the replication study ranged from 17% to 100% ($M = 71\%$, $SD = 22\%$) and did not differ significantly from the proportion of environmentally friendly choices observed in the first study.

The results of this replication study closely reproduced the findings from our first study. The proportion of environmentally friendly PEBT choices decreased with increasing individual cost of behaving environmentally friendly and increased with increasing environmental cost of behaving environmentally unfriendly, both $p < .001$. With the exception of the relationship between PEBT choices and environmental identity, $p = .018$ (one-tailed correlation), all correlations between PEBT behavior and pro-environmental self-report variables were significant at the corrected significance level of $\alpha = .0083$, all $p < .001$. None of these effects differed significantly from the effects we observed in our first validation study. As in our first study, choice behavior was highly consistent across PEBT trials. These findings indicate that the PEBT has favorable psychometric properties irrespective of the labels used to denote the two PEBT choice options.

5. Discussion

We developed the PEBT as a computerized paradigm for the assessment of actual pro-environmental behavior under controlled laboratory conditions. In two high-powered, pre-registered validation studies, the PEBT appeared to fulfill this purpose at a high level of psychometric quality. Variables that should theoretically affect pro-environmental behavior

(such as the individual cost of engaging in pro-environmental behavior and the environmental benefits of doing so) exerted strong and consistent effects on behavior on the PEBT. Variables that are theoretically related to pro-environmental behavior (such as environmental attitudes, concern, values, and identity as well as self-reported PEB) were significantly correlated to the choices participants made on the PEBT. The multi-trial structure of the PEBT further ascertained that the corresponding measure of pro-environmental behavior was highly reliable. These results were observed independent of the labeling of the PEBT response options, which supports the broad applicability of the task irrespective of the transportation options participants can access in everyday life. Our findings imply that the PEBT can serve as a promising tool for the study of pro-environmental behavior in the laboratory. We will use the remainder of this discussion to highlight how the PEBT can open new avenues for environmental psychological research and thus improve our capacity to predict, understand, and promote pro-environmental behavior.

First, the PEBT can be an important addition to correlative studies testing theoretical frameworks for the prediction of pro-environmental behavior. For practical reasons, these studies often resort to outcome measures that can be assessed within the same testing session as the predictor variables. In the absence of a standardized measure of actual pro-environmental behavior, using self-reports of pro-environmental behavior or pro-environmental intentions emerged as the predominant methodological approach in this field. Directly observable behavior on the PEBT constitutes an alternative outcome variable that is not associated with the typical limitations of self-report measures. In addition, combining self-report measures of hypothesized predictors of pro-environmental behavior (such as attitudes or values) with an objective assessment of pro-environmental behavior (such as provided by the PEBT) would address the problem of artificially inflated relationships that are due to common method variance (Kaiser, Schultz, & Scheuthle, 2007; Lindell & Whitney, 2001).

Second, the PEBT can provide an objective criterion variable that can be used to validate newly developed scales for the assessment of pro-environmental behavior or related constructs (e.g., Kaiser, 1998; Markle, 2013; Nisbet, Zelenski, & Murphy, 2009). In many situations, the use of self-report measures might be inevitable or less costly than assessing pro-environmental behavior via a behavioral task. Calibrating self-report measures against behavior on the PEBT prior to their use in these situations would substantially increase the conclusiveness of self-report research.

Finally, the PEBT has the potential to be a powerful tool for the evaluation of interventions that promote pro-environmental behavior and for the experimental analysis of the mechanisms underlying their effectiveness. In contrast to many field studies, the possibility to evaluate interventions on the PEBT is not limited to the comparison of one experimental group to one control group but may involve multiple parametrically varying conditions that allow establishing dose-response relationships. Moreover, it is possible to integrate interventions that have been studied in separate literatures to examine their interactive contribution to promoting pro-environmental behavior. This can be done while having control over the subject pool and being able to design *ceteris paribus* comparisons between conditions. In view of these advantages, we believe that the PEBT will substantially enhance the methodological possibilities in the field of pro-environmental behavior research.

5.1 Limitations

It is important to note that the PEBT versions used in our studies were optimized to examine our hypotheses and thus to provide first evidence for the validity of the PEBT. Several procedural decisions (e.g., the counterbalanced manipulation of CO_2 conditions across blocks or the randomization of trials differing in waiting times within blocks) were taken to ascertain the internal validity of our experiments. Comparable task settings might be less optimal for individual-difference studies on pro-environmental behavior. In order for such

studies to rely on an optimized version of the PEBT, future work is required to carefully select the set of PEBT items with the most favorable psychometric properties. Our data already suggests that including a larger proportion of difficult trials (i.e., trials with larger waiting time differences) may help to decrease the relatively large proportion of environmentally friendly choices and hence to prevent potential ceiling effects.

Our current version of the task can be argued to be both too abstract and not abstract enough. When designing the PEBT, we were required to trade off two competing goals. On the one hand, we wanted to create a pure laboratory measure that isolates the trade-off between individual and environmental consequences that is characteristic of many pro-environmental behaviors (Gifford, 2011; Steg, 2015). On the other hand, choices on the task should be realistic in the sense that they are made based on the same attributes and processes as concrete choices of environmental significance in everyday life. The PEBT version presented here takes up an intermediate position on a continuum between two extremes: a context-free choice between options differing solely in individual and environmental consequences and a choice that reflects all aspects of everyday transportation choices. We chose this position as a starting point because we wanted a) participants not to be confused by a too artificial setting and b) our measure not to be confined to the domain of transportation choices but to be generalizable to multiple domains of pro-environmental behavior. Nonetheless, we explicitly encourage variations of abstractness in future PEBT versions. Our replacement of meaningful with arbitrary labels for PEBT transportation labels in our replication study can already be regarded as a shift towards the more abstract end of the continuum. In similar ways, the PEBT task environment can be enriched by additional attributes that might be relevant for pro-environmental choices within or beyond the transportation domain. These adaptations should be based on a careful analysis of the contingencies involved in a particular everyday pro-environmental behavior. PEBT variations

along these lines may also contribute to an improved understanding of the similarities and differences between different pro-environmental behaviors (see also Brick, Sherman, & Kim, 2017; Schmitt, Aknin, Axsen, & Shwom, 2018).

Finally, it is important not to consider the PEBT as a panacea to all problems related to the measurement of pro-environmental behavior. The data presented here are consistent with behavior on the PEBT being a type of pro-environmental behavior, but it is only one pro-environmental behavior in one particular context. Especially with regard to research on individual differences in pro-environmental behavior, measurement approaches that rely on aggregation across different behavioral domains (e.g., Kaiser et al., 2010; Kaiser & Wilson, 2004) can be expected to capture more of the relevant variance than comparatively specific PEBT measures. However, the potential to objectively assess a behavior of actual environmental significance under controlled conditions makes the PEBT a valuable addition to the methods available in the study of pro-environmental behavior.

6. Conclusion

Valid and reliable behavioral measurements are a prerequisite for progress in the field of environmental psychology. By addressing some of the limitations of self-report measures and field assessments, the PEBT provides novel opportunities for the study of pro-environmental behavior. Systematic exploitation of these opportunities can be expected to advance our knowledge of how to encourage and support shifts towards environmentally friendly behavior.

Footnotes

[1]In order to get an overview of current practices in the study of pro-environmental behavior, we reviewed the eight volumes of the *Journal of Environmental Psychology* published in 2015 and 2016. During this time, 67 articles have been published in the subsection dedicated to the study of pro-environmental behavior (Pro-environmental Behavior/Sustainability/Sustainability, Pro-environmental Behavior, and Climate Change/Pro-environmental Behavior, Sustainability, and Climate change/Pro-environmental Concern and Behavior/Pro-environmental Behavior and Climate Change). Sixty-four of these studies contained original data; the other three were meta-analyses or reviews. Fifty-three (83%) of the 64 original data reports relied exclusively on self-reports (self-reported behavior: $k = 26$; intentions and other psychological antecedents of behavior; $k = 27$).

[2]The proportion of experimental studies is larger (6 out of 14) among those studies that use pro-environmental intentions as an outcome variable.

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