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Abstract

Many environmental nudges have succeeded in increasing pro-environmental behaviors among adults, but hardly any study tested the use of environmental nudges on younger people. We conducted a field experiment involving high school students to assess the effectiveness of a nudging strategy which aimed at motivating them to power off computers when these are not used in the classroom. Our nudging strategy resulted in a significant reduction in computer power in the treated high school compared to a control high-school. We discuss the relevance of our work for research on young people's prosocial behavior as well as the implications in terms of policy-making.

Keywords: Environmental nudges, pro-environmental behaviors, adolescents' prosocial behavior.

JEL classification: C93; D90; I20; Q50.

Research highlights:

- We provide experimental evidence from the field on the effect of nudges on adolescents' pro-environmental behavior;
- Our focus on adolescents is motivated by the fact that intervening to instill good habits at an early age is essential because it may have long lasting effects over the life span;
- We find that our nudging strategy significantly increased pro-environmental behaviors among adolescents in the treated high-school compared to the control high-school.

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1. Introduction

Behavioral science techniques to change people's behavior have been used in different domains, with the promise to make people healthier (Milkman et al., 2021), wealthier (Thaler & Benartzi, 2004) and our planet greener (Allcott & Rogers, 2014). There is extensive evidence from lab and field experiments about the conditions that make nudges effective in changing people's behavior and when they fail to make an impact (DellaVigna & Linos, 2022 ; Saccardo et al., 2024). The existing research on nudging, however, has mostly focused on the behavior of adults, and less is known about the effects of nudges on young children and teenagers. There is a burgeoning literature in behavioral economics that looks at children's behavior, with a focus on how early life influences shape later life outcomes (List et al., 2023). Nevertheless, studies testing "light-touch" interventions on children and teenagers are less common. An exception is the literature on nudging children and teenagers toward a healthier lifestyle (Lycett et al., 2017; Marcano-Olivier et al., 2019; Metcalfe et al., 2020). Intervening to instill good habits at an early age is essential because it may have long lasting effects over the life span (Balundė et al., 2020; Sullivan et al., 2022).

In this article, we provide experimental evidence regarding the effect of nudges on high school students' (15 to 18 years old) pro-environmental choices. We conducted a field experiment to test the effect of behavioral nudges on high school students' propensity to switch off computers when these are not used in a classroom. Indeed, high schools often have computer rooms where students can learn on a variety of software programs. Computers are one of the devices that are the most energy-consuming when being left on a standby mode (EDF ENR; University of Oxford; Cooper et al., 2015).[6] We tested our behavioral nudges in one high school (the treated one) and compared the power in kW of its Information Technologies (IT) system to a similar high school in terms of number of computers (the control one). We find that the treatment resulted in a significant reduction of 0.21 kW (5.95%) on average computer power in the treated high school compared to the control high school. Our research contributes to the literature on green nudges (Carlsson et al., 2021) as well as to the research on fostering prosocial behavior among adolescents (Briole et al., 2022).

2. Experimental design and implementation

Two high schools in Centre-Val de Loire (France) were selected for the study, in partnership with ENGIE, a utility company that manages all energy-related decisions in several high schools in the Centre-Val de Loire region. The two high schools (Jean Zay being the treated one and Victor Laloux the control one) are comparable in terms of the number of classroom computers (around 450 computers in each high school) as well as the occupancy rate of the classrooms with computers. In both high schools, all computers are automatically switched on at 6am and are switched off at 8pm by a centralized control system. In the meantime, most of the computers switch to a standby mode unless students or teachers use them. Even though students may have classes in a computer room, they may only need to use computers for a specific part of the class or not use them at all. Furthermore, switching off computers at the end of the class would generate environmental benefits given that the next class may not use computers or may take place only later during the day.

[6] Link to the website of EDF (French electricity company) about energy consumption of devices left on standby: https://www.edfenr.com/guide-solaire/consommation-appareil-en-veille/
Link to an Oxford University article on the same subject: https://www.it.ox.ac.uk/article/environment-and-it

We implemented nudges in one of the high schools (Jean Zay, the treated high school) but not in the other (Victor Laloux, our control high-school). When testing nudges, many interventions consist in one isolated solution. However, there is increasing evidence pointing to the limited power of nudges to change behaviors, especially when these are implemented at scale (DellaVigna & Linos, 2022; Milkman et al., 2022; Saccardo et al., 2024). We opted to use a nudging strategy that combines three elements[7]: (i) an information element that provides high school students with an information about the environmental benefits of turning off computers as well as about the time that it takes to turn it on,[8] (ii) a to-do-list that explains when to turn off the machines,[9] and (iii) an impact element informing students that turning-off computers will save time for the cleaning agents because they will not have to check whether computers are turned off after each classroom (thus, highlighting the positive impact that students may have on the cleaning staff).[10] The first two elements of our nudging strategy were designed as stickers and were fixed next to each computer in a classroom. The third element (the impact one) was designed as a poster and was widely displayed in every classroom with computers. All three elements prioritize information dissemination though evoke distinct motivations. Pictures of the stickers and the poster can be found in the *Supplementary Materials*.

The first element, i.e., emphasizing environmental benefits and informing about the time that it takes to turn on a computer, is motivated by insights that our team collected following a field visit. Following discussions with some of the teachers, it appeared that the teachers thought that it was costly to switch off computers because of the time that it takes for a computer to restart. At the same time, they were not sure that there were any environmental benefits from switching off computers compared to leaving the machines on a standby mode. Our first element, thus, aims at correcting some preexisting misperceptions about the costs and the environmental (i.e., global) benefits of having computers switched off. The second element, i.e., the to-do-list, acts as a reminder of when a computer should be switched off. There is evidence showing that some behavioral strategies are more effective when people are reminded about specific goals (Karlan et al., 2016). The third element, i.e., emphasizing time-saving benefits for the cleaning staff of the high school, is meant to activate altruistic motives as knowing that switching off computers at the end of the class will save time for the cleaning staff. Previous research has shown that people often engage in individual costly behavior with a benefit for others because they may feel some warm-glow (Andreoni, 1990) and/or a form of personal satisfaction from improving the situation of someone else (Konow, 2010).

In the treated high school, nudges were installed on September 28, 2023. We collected data from September 29 to December 15, 2023. We have access to power (kW) related to the whole IT system of

[7] On the relevance of studying nudges within a suite of nudges, see Beshears & Kosowsky (2020).
[8] "On average, turning on this computer takes no more than 1 minute. Switching it off when not in use saves 175 kg of CO_2e/year, which is equivalent to 54 journeys from Orleans to Paris by train." We wanted to reinforce good intentions with salient information. In total, four different comparisons (journeys by train, journeys by car, number of t-shirts produced and number of pants produced) were displayed to ensure that the audience identifies with at least one of them and to avoid redundancy. This information was given in the form of a sticker affixed on each computer table or computer tower.
[9] Next to the first element, was placed another sticker with the objective to facilitate the transition from intention to behavior: "The right reflex: either use or switch off".
[10] To ensure a long-term change of behavior, we chose to make salient the impact on others that one can have by adopting the good behavior. A big poster located in several strategic rooms stated "Turning off your computer after each use only takes a few seconds and saves us a lot of time every day. All the staff at Jean Zay High School thank you.".

each high school with data collected every 10 minutes.[11] We employ a difference-in-differences method to analyze the impact of our intervention on power (Angrist & Pischke, 2009). This approach enables us to compare the computer power between the high school that received the treatment and the control high school across periods with and without the treatment. Indeed, we have power data for the two high schools from September 29 to December 15, 2023, as well as for the same period but in 2022. The reason why we cannot simply compare differences between the two high schools during the treatment implementation is that there may be preexisting differences that may drive our results. Thus, we look at the difference between the two high schools over the same period but before the implementation of the nudges (from September 30 to December 16, 2022) and after their implementation (from September 29 to December 15, 2023). We next present the detailed results and a short discussion of this research's contribution to the behavioral science literature on pro-environmental behavior.

3. Results

3.1 Checking for the validity of our data before and during the implementation of nudges

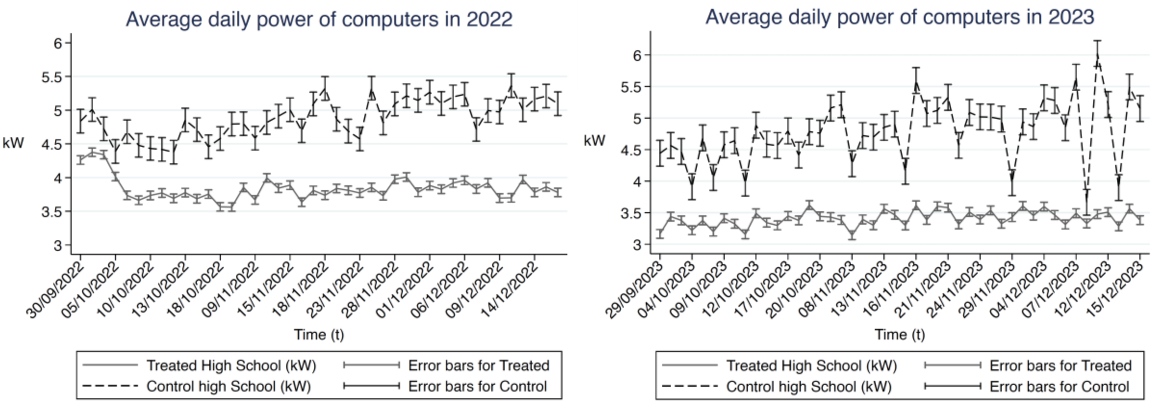
The difference-in-differences method is appropriate to measure the average treatment effect (ATE) on the treated. We describe first the necessary conditions that must be met in order to use this method.[12] Figure 1 presents the evolution of mean daily power related to the IT system in each high school in 2022 and 2023.[13] Figure 1 allows us to validate one of the necessary assumptions required to use the difference-in-differences method, which is the parallel trends of power during the pre-treatment period. The days between October 22, 2022, and November 6, 2022, as well as those between October 21, 2023, and November 5, 2023, have not been considered as these were school vacations.

Figure 1. Average daily power for pre-treatment period and post-treatment period (weekends have been removed to make it easier to observe parallel trends on days when computers are in use)

[11] We also have access to daily energy consumption (kWh) related to the whole IT system. However, as it was collected only once a day, we did not use this measure for data analysis. Our results do not change when using daily energy consumption.

[12] The hypotheses that need to be validated before using the difference-in-differences method are the parallel trends assumption and the Stable Unit Treatment Value Assumption (SUTVA), which includes stability of composition of intervention, stability of composition of comparison groups, and no spillover effects of treatment onto untreated units.

[13] In the following sections of the paper, we refer to 2022 vs. 2023, but the reader should bear in mind that the exact period is from September 30 to December 16, 2022 for the pre-treatment period, vs. from September 29 to December 15, 2023 for the treatment period.



To ensure the comparability of the two high schools in terms of power prior to the intervention, and thus validate comparisons between groups, we employ an additional tool: the normalized difference. Following Imbens & Rubin (2015), the calculation of normalized differences between both high schools for power related to computers in 2022 yield a value of -0.265. [14] A difference below 0.25 in absolute value is balanced (Imbens & Rubin, 2015). Our value being slightly above 0.25 in absolute value, this indicates an acceptable imbalance.

The other condition that is worth discussing in our context is whether nudges (in the form of stickers and posters) that were installed lasted in time or were removed by the high school students, thus limiting the exposure of students to our behavioral interventions. Following a field visit, we confirmed that none of the stickers and posters had been removed during the study. Furthermore, another important design feature to be noted is that the two high schools are located in different cities, thus excluding the possibility of contamination effects. Finally, the composition of high schools was stable during our field experiment, as both high schools had similar numbers of students, teachers and staff between 2022 and 2023. These three points allow us to validate the Stable Unit Treatment Value Assumption (SUTVA), thus allowing us to identify the causal effect of our nudges on high-school students' behavior.

3.2 Results after the implementation of nudges

Figure 2 shows the average power related to the use of computers in both high schools in 2022 and 2023. In 2022, the average power related to the use of computers in the control high school was 11.73% higher than in the treated high school, while the difference in 2023 was 18.65%.

[14] Normalized difference calculation: $\frac{\overline{X_t}-\overline{X_c}}{\sqrt{(s_t^2+s_c^2)/2}}$. $\overline{X_t}$ and s_t^2 are the mean and standard deviation of computer power of the treated high school, $\overline{X_c}$ and s_c^2 are those of the control high school.

Figure 2. Average power of computer systems (kW)

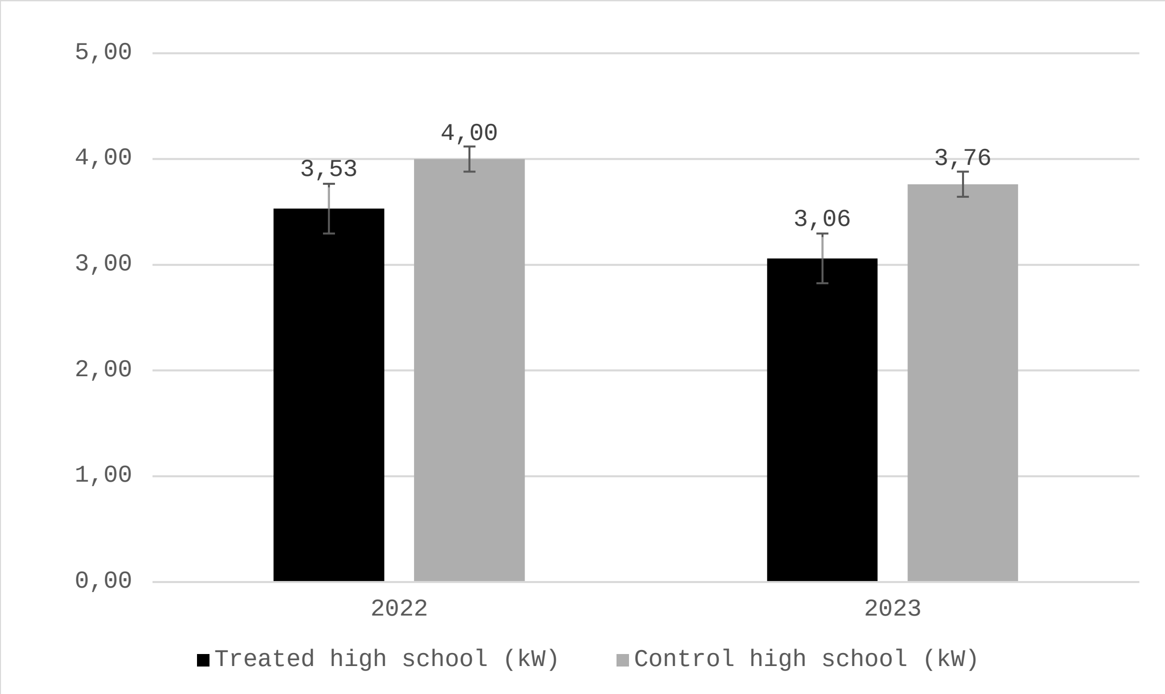


Table 1 shows the regression results when applying the difference-in-differences method. The estimate of the ATE is indicated by the coefficient of the interaction variable between Time and Treatment. It is equal to -0.21 which shows that the treatment resulted in a significant reduction of 0.21 kW of average computer power in the treated high school compared to the control one. Comparing this computer power in the treated high school between 2022 and 2023, we conclude that the treatment resulted in a 5.95% reduction on average of computer power that can be attributed to the use of nudges.

Table 1. Difference-in-differences regression.

Power (kW)	Coef.	s.e.	t	$p > \|t\|$	[95% Conf. Interval]
Time	-0.280***	0.032	-8.703	0.000	-0.343 ; -0.217
Treatment	-0.479***	0.033	-14.55	0.000	-0.544 ; -0.415
Time*Treatment	**-0.207*****	0.045	-4.545	0.000	-0.296 ; -0.118
Constant	4.017***	0.023	172.6	0.000	3.972 ; 4.063
Observations	36,239				
R^2	0.026				
Adjusted R^2	0.026				

**** p<0.01, ** p<0.05, * p<0.1*

Note: Dummy variable "Time" takes on the value of one for post-treatment period. Dummy variable "Treatment" takes on the value of one if the high school received the treatment.

4. Discussion and conclusion

Our field experiment studies the effect of nudges to encourage high school students to switch off classroom computers when not used, thus enabling a reduction in energy consumption. Combining several behavioral nudges, we showed that high school students significantly changed their behavior in the treated high school compared to the control one. Our nudging strategy was composed of three complementary elements : a sticker providing information about the environmental benefits of turning off computers using analogies as well as about the time it takes to turn on computers; a sticker showing a to-do list to remind people to turn off computers when not in use; and, a poster thanking students for saving staff time by turning off computers themselves. Our nudging strategy resulted in a significant reduction of 0.21 kW on average of computer power in the treated high school, which represents a 5.95% reduction on average of computer power in the treated high school during the treatment period that can be attributed to the use of nudges. It is important to remember that the savings achieved, while modest, stem from stickers and posters that can be easily and inexpensively replicated in other high schools. It is conceivable that, on a larger scale, our intervention could result in significant energy savings. Furthermore, the effect size in our study is comparable to what many other studies using nudges have found (Saccardo et al., 2024).

Numerous field experiments have been conducted on adults to motivate pro-environmental behavior finding that nudges can have a significant positive impact. For example, in a large-scale field experiment, Bhanot (2021) found that using injunctive norms can lead to significant reductions in residential water consumption. Alonso-Pauli et al. (2022) succeeded in increasing participation in waste sorting by about 8 percentage points by simply offering soft commitments to residents from Palma, Spain. Similarly, using data from a natural field experiment on 42,100 households, Brandon et al. (2019) found that a combination of two nudges reduced peak load electricity consumption by nearly 7%. These studies focused on solutions implemented on an adult population. However, children and teenagers may respond to nudges in a different manner. For instance, younger people could pay less attention to nudges or be less sensitive to some of their underlying mechanisms (e.g., social comparison, the benefits and costs of some action, the saliency of one's impact on the environment, etc.). We find that nudges, using the three elements presented above, can significantly change teenagers' behavior in the classroom.

To conclude, we can outline some limitations of our study. The first limitation to note is that employing a strategy composed of three nudges does not allow us to isolate the effect of each nudge individually. Nevertheless, for public decision-makers, the overall effectiveness of a solution in achieving a goal may be more important than identifying which specific component is responsible for the outcome. From a policy perspective, the question is whether a nudging strategy can be implemented in other locations at a low cost. Printing and affixing the stickers and posters that we designed is a low cost process. The second limitation relies on studying spillover effects. Changing behavior in the classroom may have consequences on related behaviors at home, such as switching off computers, tablets, lights or any other devices at home, and even on behaviors of family and friends. Unfortunately, the schedule of the field experiment did not allow us to measure such spillover effects. In addition, as we were not able to observe individual decisions, we focused on aggregate measures of computer usage. Consequently, it would be interesting to observe how students use computers and how they respond individually to our nudges. Furthermore, we collect data related to computers and other devices, such as printers, but we only targeted the use of computers. Although computers account for the largest share of power related to the IT system, we cannot isolate the power of computers from the other IT devices. At the same time, this implies that we estimate a lower bound for the effect of our nudges. Indeed, if all the IT devices were targeted, the effect could be larger.

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Supplementary materials: Nudges implemented in the field

(i)

"The right reflex: either use or switch off"

(ii)

"On average, turning on this computer takes no more than 1 minute."

"Switching it off when not in use saves 175 kg of CO_2e/year, which is equivalent to a car journey from Orléans to Nice."

(iii)

"Turning off your computer after each use takes a few seconds and saves us a lot of time every day."

"All the staff at Jean Zay High School thank you."

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WP 2024-15	Rustam Romaniuc, **Odile Séré de Lanauze**, **Lisette Hafkamp-Ibanez**, & **Sébastien Roussel** « Field evidence on nudging high school students towards pro-environmental behavior »