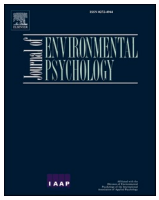
Journal of Environmental Psychology 108 (2025) 102852

Contents lists available at ScienceDirect

Journal of Environmental Psychology

journal homepage: www.sciencedirect.com/journal/journal-of-environmental-psychology



Psychological interventions for environmental impact: A field experiment on reducing engine idling

Zoe Horsham [a,b,1], Sarah Lily Resanovich [b,1,*], Fanny Lalot [b,c], Tim Hopthrow [b], Dominic Abrams [b]

[a] Kent Business School, University of Kent, Canterbury, UK
[b] Centre for the Study of Group Processes, School of Psychology, University of Kent, Canterbury, UK
[c] Faculty of Psychology, University of Basel, Basel, Switzerland

ARTICLE INFO

Keywords:
Pro-environmental behavior
Field experiment
Air quality
Community impact
Social influence
Informational influence

ABSTRACT

A large-scale field experiment ($N = 8948$) tested psychological interventions to reduce engine idling at short-wait stops. Persuasive messages based on social influence, informational influence, and identity-based influence/community engagement were displayed at a busy intersection. This study extends previous research by (1) considering shorter waiting times (i.e., red light stops) and (2) investigating the effect of messaging over longer time periods, including post-intervention. Compared to pre-intervention baseline, all messages significantly reduced idling rates in the first phase of the experiment, by 6–16 %. The effect was retained two weeks after signs were removed. In the second phase of the experiment, the most effective message (informational influence) was displayed again over four weeks, revealing a sustained effect on engine idling reduction that persisted one week after the sign was removed. This field experiment supports the efficacy of theory-driven messaging interventions to trigger sustained pro-environmental behavioral changes. Future studies may investigate the generalizability of the present findings to other settings. We highlight implications for psychology-based pro-environmental interventions.

1. Introduction

Air pollution poses great risks to the environment, human health, and wellbeing. Traffic emissions are amongst the largest contributors to air pollution (Department for Environment, Food & Rural Affairs, 2017), accounting for ~40 % of nitrogen oxide (NO_x) emissions in Europe (European Environment Agency, 2022). Thus, there is a critical need for interventions to mitigate vehicle emissions.

A significant contributor to traffic emissions is engine idling, defined as continuous running of the engine, whilst the vehicle is stationary. Vehicles idling for 30 s produce twice the quantity of NO_x as those who switch their engines off and back on again (Transport Research Laboratory, 2021). Targeting idling behavior is thus an effective strategy to reduce traffic emissions (Abrams et al., 2021).

1.1. Behavioral interventions to reduce idling

Research has demonstrated the efficacy of behavioral interventions to reduce idling (see Lalot et al., 2025, for a recent review). In the UK, an anti-idling campaign where volunteers directly requested drivers to switch their engines off found a small but significant reduction (8 %) in idling over a four-year period (Idling Action London, 2022). However, such interventions are resource- and time-intensive, and unlikely to reduce engine idling when volunteers are not present. Furthermore, behavioral improvements were inconsistent over time.

Driver survey data found banners/signage tactics were rated more engaging than being directly approached by volunteers (Idling Action London, 2022). Thus, anti-idling campaigns using persuasive messages may be a more cost-effective (Bergquist et al., 2019) and positively perceived strategy. Research demonstrates significant effects of anti-idling campaigns in school drop-off zones (Eghbalnia et al., 2013;

* Corresponding author.
E-mail address: s.resanovich@kent.ac.uk (S.L. Resanovich).
[1] Co-First Authors.

https://doi.org/10.1016/j.jenvp.2025.102852
Received 14 March 2025; Received in revised form 13 October 2025; Accepted 17 November 2025
Available online 20 November 2025

Mendoza, et al., 2022; Mendoza, et al., 2022; Rumchev et al., 2021) and, more specifically, of persuasive road sign messages, on reducing idling behavior (Abrams et al., 2021; Mahmood et al., 2019; Meleady et al., 2017; Player et al., 2018; Van de Vyver et al., 2018) and improving air quality (Abrams et al., 2021; Rumchev et al., 2021).

Whilst such findings provide insights into the efficacy of persuasive messages on reducing idling, prior research focused on idling in zones with long average waiting times relative to, for example, traffic light stops (e.g., Railway crossings, Abrams et al., 2021; school drop-off zones; Rumchev et al., 2021). Drivers may be more likely to switch off their engines during longer waits due to greater perceived financial and environmental impacts. More predictable waiting periods also allow drivers to better gauge whether it is "worth it" to turn off their engines (Dogan et al., 2014). It is not currently understood whether the effects of persuasive messages generalize to shorter, more varied idling periods.

Furthermore, prior research only investigated short-term effects of persuasive message interventions. Repeated exposure to persuasive messages could diminish "novelty effects" (Rämä & Kulmala, 2000), and through this, depth of processing (Shi & Smith, 2016). Thus, long-term exposure may lead to lower acceptance (Cacioppo & Petty, 1979) and behavioral compliance (Skilbeck et al., 1977). It is possible therefore that the impacts of persuasive road sign messages diminish over time, warranting further investigation into their long-term efficacy.

1.2. The present research

The present research extends previous studies by investigating long-term effects of persuasive messaging on idling behavior. It also examines the efficacy of persuasive messages for shorter idling periods (at red traffic lights) to determine their effectiveness in a wider range of traffic contexts, thus addressing two limitations of the existing literature (Lalot et al., 2025). We next describe the rationale for our chosen persuasive messages.

1.2.1. Social influence and persuasive messaging

Psychological theories propose different types of influence, amongst which three are especially relevant for pro-environmental behavior: (i) *normative influence* (e.g., Nolan et al., 2008; Schultz et al., 2008); (ii) *informational influence* (e.g., Vandenbergh et al., 2011); and (iii) *identity-based influence* (e.g., Terry et al., 1999; Van Vugt, 2001). Here, we compare the efficacy of three persuasive messages on reducing idling behavior, each targeting one form of influence: two that were identified as effective in past research on engine idling (normative and informational influence) and one newly developed message (identity influence).

Normative influence messaging. Normative influence messaging encourages pro-environmental behavior by appealing to ingroup social norms (Cialdini & Goldstein, 2004; Keizer & Schultz, 2018; Schultz et al., 2007). Focus Theory of Normative Conduct (Cialdini et al., 1991) distinguishes between *descriptive* norms (what most people do) and *injunctive* norms (what people (dis)approve of).

Both types of norms can influence pro-environmental behavior. Cialdini et al. (1990) found that a descriptive anti-littering norm (a litter-free environment) *and* an injunctive anti-littering social norm (message disapproving of littering) were both independently associated with lower littering rates. A meta-analysis by Bergquist et al. (2019) confirms the efficacy of descriptive and injunctive norms on pro-environmental behaviors, particularly in individualist cultures.

However, the relative efficacy of norms is dependent on the social context in which they operate. Descriptive norm messages are more effective in contexts where the desired behavior already commonly occurs, since they reinforce conformity pressures. In low-compliance contexts, such messages risk backfiring by drawing attention to prevalent non-compliant behavior (Cialdini et al., 1990). Injunctive norm appeals are theorized to produce more reliable positive behavioral effects in low-compliance contexts, since they do not depend on observed behaviors of others (Cialdini et al., 1991). Unexpected or backfiring effects can also occur when norms contradict (Schultz et al., 2007), as illustrated with engine idling behavior by Mahmoudi et al. (2025). When implementing norm messaging, it is thus important to take context into account.

This study investigates anti-idling behavior at short wait intervals (i.e., red traffic lights), where idling is prevalent (Eichler, 2018).[2] For this low compliance context, we thus developed an anti-idling message appealing to injunctive driver norms. Prior field experiments have demonstrated the effectiveness of road sign messages appealing to injunctive norms or highlighting positive ingroup deviance on idling behavior at railway crossings (Abrams et al., 2021; Player et al., 2018). We extend these studies by testing whether this effect would similarly be found for red light stops.

Informational influence messaging. Behavioral change can also be enacted through informational influence, whereby one changes their underlying beliefs towards a behavior as they gain more knowledge (Deutsch & Gerard, 1955). Informational influence is particularly likely when one wishes to resolve uncertainty (Festinger, 1954) and is motivated to learn about a specific issue (see Petty & Cacioppo, 1986). Environmental psychology research has identified beneficial effects of informational interventions, especially for those with strong environmental values (Bolderdijk et al., 2013) and in the absence of strong situational constraints (Kaiser & Fuhrer, 2003; Schultz, 2014).

Engine idling should be amenable to informational interventions given its controllable nature and convenience. Studies have identified a positive effect of anti-idling campaigns with a strong informational component Mendoza, et al., 2022; Mendoza, et al., 2022; Rumchev et al., 2021). However, reviews highlight that information in isolation is insufficient to trigger significant pro-environmental behavioral change (Bergquist et al., 2023; Osbaldiston & Schott, 2012). In the absence of a motivational driver, increasing knowledge rarely leads to increased pro-environmental behaviors (Schultz, 2014; Sigurjonsdottir et al., 2022). The cause of this knowledge-action gap is unclear-potential suggestions include negative climate anxiety and feelings of powerlessness (Hussey, 2023; Lorenzoni et al., 2007).

Positively framed informational influence messages containing clear instructions are argued to be more effective, enhancing perceived environmental efficacy and reducing climate anxiety (Frick, Kaiser, & Wilson, 2004; Hussey, 2023). Supporting this, Nelson et al. (2020) found that informational influence messaging reduced single-use plastic bag purchases. Similarly, Abrams et al. (2021) found positively framed informational messaging led to a 25 % reduction in idling. We thus developed and tested a positively framed, informational influence-driven persuasive message to explore its efficacy for reducing idling at red light stops.

Identity influence messaging. Whilst normative influence encourages conformity to avoid exclusion or ostracism from others, identity influence intrinsically motivates deeper behavioral change to align with one's group identity (Spears, 2021).

According to referent informational influence model, identity strength determines how strongly group behaviors and expectations influence us (Abrams et al., 1990; Abrams & Hogg, 1990; Terry & Hogg, 1996; Turner et al., 1987). Prior research supports the efficacy of community-based social identities in pro-environmental behavior interventions. For example, Nolan et al. (2008) found promoting energy conservation as characteristic of people in the same residential area had

[2] Reports an unpublished trial study by Meleady and colleagues finding idling rates of approximately 90 % at red lights.

Fig. 1. Data collection locations at the intersection of three roads.
Note. Image provided via Google Maps. Arrows indicate data collection points (dashed arrow = data collection point A; solid arrow = data collection point B). Crosses indicate road sign locations. Diamonds indicate traffic lights. Locations are approximate for illustrative purposes only.

the greatest effect on reducing energy consumption. Seyranian et al. (2015) similarly found messages using inclusive language linking pro-environmental behavior to local community identities reduced water consumption (see also Lede et al., 2019).

Real-world applications of identity influence may be best embedded in a community-involvement approach. There has been a recent push to recognize the importance of contextualized behavior and active community engagement in research (Lalot et al., 2025; Trott et al., 2020). Among others, Mehdipour et al. (2024) provide an example of participatory action research project that focused on community co-generation in Florida, which yielded successful outcomes by increasing trust between researchers and participants and empowering participants to share their lived experiences.

In addition to enriching the research process community engagement also enhances psychological ownership and personal involvement (Burn & Oskamp, 1986), both of which may increase persuasive message efficacy. *Bottom-up initiatives* can exert stronger effects on pro-environmental behavior intentions by promoting pro-environmental identities (Jans, 2021) and perceptions that the message comes from ingroup members (Abrahamse & Steg, 2013).

Our study incorporates a bottom-up approach via a community-generated message. Prior to the experiment, two community workshops were conducted to generate identity influence messages. The message with the most votes on a community forum public poll was ultimately selected (see Electronic Supplementary Material, SM1). We thus sought to extend community engagement research to an anti-idling context, fostering identity influence via community-created messaging that promoted switching off engines as characteristic of one's community. By giving the community control of the identity influence we were ensuring that the community got to define their own identity within the message they created.

1.2.2. Overview

We conducted a large-scale field experiment to assess the effectiveness of three persuasive message interventions to reduce idling at red lights. The experiment consisted of two phases, encompassing a total of eight alternating intervention and 'recovery' periods. Phase 1 compared the messages with a pre-intervention baseline measure. All messages were expected to increase compliance (i.e., reduce idling) compared to baseline, though we made no predictions as to which would be most effective. We consequently analyzed the preliminary data and adopted the most effective message for Phase 2, testing long-term efficacy to evaluate habituation effects and persistence after the sign was removed. We expected that, although the effect of the intervention on idling reduction may decrease with time, it would remain significantly higher than pre-intervention baseline.

Analyses were conducted using RStudio 2024.04.2 + 764, with packages *lme4* (Bates et al., 2015), *lmerTest* (Zeileis & Hothorn, 2002) and *multcomp* (Hothorn et al., 2008) and following guidelines by Sommet and Morselli (2017) for multilevel analyses. All data, materials, and code for analyses are publicly available on the OSF: https://osf.io/h9z38/. The study was not pre-registered.

2. Method

2.1. Data collection

The methodology received approval from the Psychology Ethics Panel at the University of Kent. Obtaining informed consent was not feasible for this observational study. No personal data were collected, and all participants remained anonymous. The final sample consisted of 8948 vehicles traveling through a busy intersection in Rainham, Medway, between March and July 2023. Data were collected at two points of an intersection of three roads (see Fig. 1). This intersection was chosen as it was identified as the busiest intersection in the only Air Quality Management Area in Rainham (Medway Council, 2024). Data were collected by University of Kent researchers and community volunteers. Volunteers were trained prior to data collection to maximize consistency and ensure safety protocols were followed.[3]

During each red-light duration, recorders walked from the red light to the back of the queue and manually recorded vehicles' engine idling status, type of vehicle, number of vehicles in the queue, position of the

[3] Observer reliability could not be formally measured during observer training due to practical constraints of volunteer availability requiring training to take place on the same day as the volunteer's first data collection session. Alignment between the researchers and volunteers was informally assessed by asking volunteers to verbally code vehicles for the researcher until the researcher was sufficiently satisfied with the accuracy of the volunteer's coding and the volunteer felt confident to collect data independently.

Table 1
Overview of testing periods of phases 1-2.

Testing period	Condition	Number of vehicles	Vehicles with engine off (%)
Phase 1			
March 14–16	Pre-intervention baseline	1852	9.0
March 21–23	Social influence	1305	21.3
March 28–30	Informational influence	815	25.4
April 18–20	Identity influence/Community engagement	1090	15.7
May 2–4	Post Phase 1	841	15.1
Phase 2			
June 6–8	Informational influence (2)	985	20.3
July 4–6	Informational influence (3)	1315	17.9
July 18–20	Post Phase 2	745	17.1
Total		**8948**	**16.9**

Fig. 2. Persuasive road sign messages: Informational, normative, and identity influence.

vehicle in the queue, and red-light duration.[4]

Phase 1. The first testing period lasted six weeks starting March 14th, 2023. During the first week, no signs were erected and baseline data were collected. Each sign was then tested for one week. There was a two-week break between the second and third signs as traffic patterns changed due to school holidays. After the third sign was removed, there was a one-week break, followed by a week of post-phase 1 data collection without any signs.

Phase 2: Longer-term testing. The second phase re-tested the most successful sign from Phase 1 (informational influence). The sign remained at the intersection for one month. Data were collected at the start of June and July. The sign was taken down in the second week of July and a final round of data collection occurred one week later. Table 1 provides an overview of Phases 1 and 2.

We observed 8948 vehicles (6715 cars, 1234 vans, and smaller numbers of lorries, buses, and taxis). Across both phases, an average of 83.1 % of drivers left their engines idling. Following Abrams et al. (2021), we conducted analyses on all vehicles. Robustness checks conducted only on cars yielded similar results (see SM2).

2.2. Materials

Intervention messages were printed on 1050 × 750 mm signs, in black text over yellow backgrounds to stand out. Three messages were printed (Fig. 2 and Table 2). The social influence and informational influence messages were adapted from Abrams et al. (2021). The identity influence message was generated through community workshops (SM1) (see Table 3).

We conducted a supplemental online study to assess face validity and perceived effectiveness of each message. Results showed participants linked all messages to the corresponding influence process significantly above chance levels (identification accuracy = 63–85 %), demonstrating satisfactory face validity (see SM3).

[4] Signs were erected at the start of each week on Monday. Data collection periods were Tuesdays and Thursdays at 9:30–10:15am, 12:00–12:45pm, and 4:00–4:45pm. There was at least one researcher or volunteer per data collection point for all data collection periods. Coders were trained and instructed to avoid eye contact with drivers and walk continuously as they coded the vehicles to avoid attracting attention. All researchers wore plain clothes to further minimize attention. A few instances occurred where drivers or pedestrians asked what the researchers or volunteers were doing, to which all had been previously instructed to respond 'a traffic observation study'. When queues continued around road bends, the recorder noted the number of vehicles they could see instead of number of vehicles 'in the queue'. Specific criteria for a minimum number of vehicles were not established. However, cases where lights changed less than 10 s after the coded vehicle(s) became stationary, or when emergency and incident support vehicles required vehicles to provide immediate access, were either not recorded or excluded during analysis.

Table 2
Persuasive road sign messages: Informational, normative, and identity influence.

Type of message	Text displayed on sign
Social influence	Join Rainham's responsible drivers. Engines off when the lights are red
Informational influence	Turn off your engine at red lights to improve air quality in the area
Identity influence/Community engagement	Lights Red, Engines Dead. #BeMoreRainham

Table 3
Engine off: Multilevel regression analysis comparing each intervention phase to pre-intervention baseline and Tukey's post-hoc comparisons with previous phase.

	Multilevel regression analysis					Tukey's post-hoc comparisons			
Fixed effects	*b* (*SE*)	*z*-test	*p*-value	Odd ratios	OR 95 % CI	*b* (*SE*)	*z*-test	*p*-value	95 % CI
Intercept	−2.34 (0.089)	26.25	<0.001	0.10	[0.08, 0.11]	–	–	–	–
Social influence	1.03 (0.109)	9.46	<0.001	2.79	[2.25, 3.45]	–	–	–	–
Informational influence	1.24 (0.119)	10.48	<0.001	3.46	[2.74, 4.36]	−0.22 (0.109)	−1.98	0.49	[-0.54, 0.11]
Identity influence/Community engagement	0.64 (0.120)	5.40	<0.001	1.91	[1.50, 2.40]	0.60 (0.118)	5.05	<0.001	[0.23, 0.95]
Post phase 1	0.59 (0.128)	4.57	<0.001	1.80	[1.39, 2.31]	0.06 (0.133)	0.44	0.99	[-0.34, 0.46]
Informational influence (2)	0.96 (0.118)	8.11	<0.001	2.60	[2.06, 3.27]	0.37 (0.132)	2.80	0.094	[-0.02, 0.76]
Informational influence (3)	0.80 (0.110)	7.27	<0.001	2.23	[1.79, 2.76]	−0.15 (0.112)	−1.37	0.87	[-0.49, 0.18]
Post phase 2	0.75 (0.135)	5.57	<0.001	2.12	[1.62, 2.76]	0.05 (0.130)	0.39	0.99	[-0.34, 0.44]

Note. Positive coefficients indicate greater likelihood that engine is turned off, compared to pre-intervention baseline. Conditions (phases) are presented in chronological order. Tukey's post-hoc comparison compared each intervention phase to the preceding phase.

3. Results

3.1. Analysis strategy

Data were organized in a hierarchical nested structure, with observations collected during specific sessions (or red lights) across observation days and locations. We therefore relied on multilevel regressions including session, date, and location, as random factors (ICC = 0.015). Engine idling was dummy coded (engine on = 0, off = 1). Intervention phase was entered as a categorical factor with "pre-intervention baseline" = 0 so the effect of each message would be compared to this initial baseline.[5]

3.2. Results

Phase 1. Multilevel analysis revealed that for all intervention phases, there was a significant increase in the likelihood of engines being turned off compared to pre-intervention baseline, with Odd Ratios (OR) ranging 1.91–3.46 (Table 3 and Fig. 3). Crucially, the positive effect of the messages was retained after sign removal: the likelihood of engines being turned off was significantly higher at post-intervention compared to pre-intervention baseline (OR = 1.80). We conducted post-hoc comparisons (Tukey's Honestly Significant Difference test) to complement these findings (see Table 2).

The messages were presented in a fixed order, potentially introducing order effects. We conducted a supplemental analysis that included time as a fixed effect and controlled for autocorrelations between consecutive observations. The effect of the messages were unaffected by these introductions, strengthening our confidence in the results (see SM5 for detailed results).

Phase 2. Results showed again that, for both intervention phases, there was a significant increase in the likelihood that engines were turned off, compared to pre-intervention baseline (ORs = 1.80–2.60; see Table 2 and Fig. 3). Post-hoc comparisons revealed two important findings: first, retaining the same message for a month did not significantly reduce its effectiveness (i.e., Informational influence #3 vs. Informational influence #2) and resulted in only a descriptive decrease of 2.4 percentage points. Second, the likelihood that engines were turned off did not decrease one week after the last sign was removed (i.e., Post-Phase2 vs. Informational influence #3).

4. Discussion

A large-scale field experiment investigated the impact of persuasive messages on engine idling through two phases, comprising eight weeks of observations at red lights at a busy intersection. During Phase 1, all three messages significantly reduced engine idling. Comparisons revealed the informational influence message was most effective. We then tested the effectiveness of this message over a further one-month duration in Phase 2, finding sustained effects on idling reduction.

4.1. Theoretical contributions

Phase 1 findings support previous literature demonstrating the impacts of persuasive messaging on environmental behavior (e.g., Nolan et al., 2008), specifically idling behavior (Abrams et al., 2021; Mahmood et al., 2019; Meleady et al., 2017; Player et al., 2018; Van de Vyver et al., 2018; see Lalot et al., 2025, for a recent review). We contribute novel evidence for the efficacy of these interventions in shorter idling durations, suggesting even brief exposure to persuasive messages can induce pro-environmental change.

Meta-analytic reviews have found information-based interventions yield consistently weaker effects on pro-environmental behaviors (e.g., Bergquist et al., 2023; Osbaldiston & Schott, 2012). Conversely, we found the informational influence message was the most effective during Phase 1. This highlights the importance of including positively framed, clear and actionable guidance to increase the efficacy of informational influence messaging by overcoming feelings of anxiety and helplessness (Frick et al., 2004; Hussey, 2023).

This reasoning may also explain why the community-developed message, which in comparison lacked clear instruction, showed the weakest effect on idling reduction. Whilst this is only one possible explanation, our research contributes preliminary support for the value of specific and actionable guidance in education-based pro-environmental interventions to overcome affective and cognitive barriers to behavioral change.

The key advancement of this study lies in Phase 2, which tested the effects of persuasive messaging over a longer duration. We found no

[5] We initially ran both the constrained intermediate model (CIM; random intercept only; ICC = 0.015) and augmented intermediate model (AIM; random intercept and slope; ICC = 0.093). The likelihood ratio test showed the AIM did not significantly improve model fit compared to the CIM, $\chi^2(df = 108) = 105.41$, $p = .55$. We therefore retained the simpler CIM for further analyses. A more detailed description of the multilevel analysis is presented in SM4.

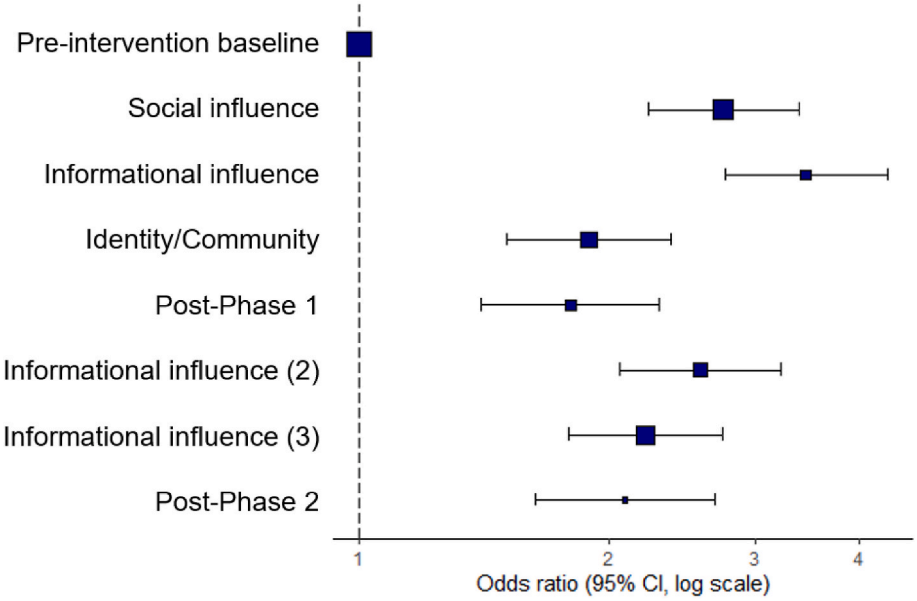


Fig. 3. Engine off: Odd ratios comparing each intervention phase to pre-intervention baseline.

evidence of habituation effects across a one-month period, providing confidence that long-term exposure to pro-environmental messaging does not necessarily undermine its effectiveness.

Furthermore, the effect was maintained after sign removal, suggesting persuasive messages can promote durable pro-environmental behavioral change via informational influence-driven belief change (see Kaiser & Fuhrer, 2003). Final baseline engine-off rates were lower than rates following first message introduction, suggesting the sign served as a valuable reminder to switch off engines.

4.2. Practical implications

There is an interest among community members and public authorities in initiatives to increase environmentally sustainable behavior. Previous studies show that reducing engine idling improves air quality (Abrams et al., 2021; Rumchev et al., 2021). The present research demonstrates investments into such interventions can deliver longer-term effects, opening up multiple pathways for practitioners, policymakers, and community organizers. We recommend these findings be utilized to add behavioral-focused components to air quality management plans. Additionally, this intervention could be adopted by institutions with high traffic volumes (e.g., universities and hospitals).

The location of these intersections is a busy high street, near many local businesses and schools. Therefore, commuters would have likely been exposed to each message multiple times. However, it remains unknown how much the intervention may have enforced a habit of switching off engines in other locations. Larger-scale studies, assessing driver behavior at multiple locations (likely requiring partnership of dedicated localities), will be useful to determine exactly how much the new behavior generalizes across settings.

4.3. Limitations, avenues for future research, and conclusion

Our messages were presented sequentially and only in one location. Therefore, it is possible that findings were influenced by order effects – though supplemental analysis shows the effect is robust to the inclusion of time effects and autocorrelation between consecutive observations. Consequently, we are hesitant to endorse one message as objectively "best" and call for future research to replicate and extend these findings. Researchers may conduct observations at multiple sites, randomize message order, and include control sites without signs, to establish robustness.

Our study is also limited in displaying only one medium – static road signs. Future research may extend our findings by testing the effects of persuasive messages via other channels (e.g., social media campaigns or bumper stickers). Qualitative research could further supplement the present findings by exploring drivers' perceptions and interpretations of messages.

Expanding the use of community workshops like those utilized in this study can increase the ecological validity of findings and foster community engagement. In this study we explored using community created messages. The level of community-engagement work in environmental psychology research can and should be extended in future work by increasing co-creation and testing the effects of participation. This could be done through developing identity/community-based messaging through focus groups can help us understand the public's perception of the messaging and follow ups with participants during and after the intervention.

Yet, it is important to remember that people may not accurately predict the effectiveness of interventions (Abrams et al., 2021; Nolan et al., 2008), underscoring the importance of pre-testing. It is clear that engaging communities can improve environmental psychology's impact (see Trott et al., 2020). However, with increased community co-creation researchers also relinquish a level of control over the interventions. Such initiatives are often more effective when they are theory-driven (Lalot et al., 2025), making it an important challenge for future psychology research to better understand how to bring together community voices and empirical evidence to design the best interventions to encourage pro-environmental behavior.

Given advances in automotive technology (such as start-stop systems and increasing uptake of EVs), it could be argued that engine idling will cease to be such a significant problem in years ahead. However, this transition is slow and predominantly involves wealthier parts of the populations and those in the Global North. Elsewhere, car ownership continues to increase, with many developing nations continuing to rely heavily on combustion engine powered vehicles (UN Environment Programme, 2024). Moreover, even with hybrid and auto stop-start technology in place, environmentally destructive engine idling is still prevalent as users often choose to deactivate it for various reasons (Nordhoff, 2024), whilst even EV drivers may continue with unnecessary energy use (Kushwah & Oshiro Caldeira, 2025). Thus, it seems highly likely that reducing engine idling will continue to be an

important objective for tackling traffic-related environmental impact. Together with legislative and physical traffic management methods, changing volitional behavior through psychological interventions will continue to be a valuable, affordable and cost-effective means of achieving that objective.

CRediT authorship contribution statement

Zoe: Writing - original draft, data curation, investigation Sarah: Writing - original draft, project administration, formal analysis, investigation Fanny: Writing - original draft, formal analysis, visualisation, validation Tim: Writing - review & editing, Supervision, Funding acquisition, investigation, resources, methodology Dom: Writing - review & editing, Supervision, Funding acquisition, methodology

Author note

This project was supported by a Kent Innovation & Enterprise funding (project "Switch off Signage Project in Rainham with Medway Council") awarded to TH and DA. FL is supported by the Swiss National Science Foundation (PZ00P1_216373/1).

We are grateful to Alan Stockey and Stuart Steed, Environmental Protection Officer, Medway Council for their assistance in finding volunteers, helping to coordinate the workshops, and for their support. We would also like to thank all of the community members who contributed to the workshops and to data collection.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2025.102852.

Data availability

Data, materials, and code for analyses are publicly available on the OSF: https://osf.io/h9z38/

References

Abrahamse, W., & Steg, L. (2013). Social influence approaches to encourage resource conservation: A meta-analysis. *Global Environmental Change, 23*(6), 1773–1785. https://doi.org/10.1016/j.gloenvcha.2013.07.029

Abrams, D., & Hogg, M. A. (1990). Social identification, self-categorisation and social influence. *European Review of Social Psychology, 1*, 195–228. https://doi.org/10.1080/14792779108401862

Abrams, D., Lalot, F., Hopthrow, T., Templeton, A., Steeden, B., Özkeçeci, H., Imada, H., Warbis, S., Sandiford, D., Meleady, R., Fell, E., Abrams, Z., Abrams, A., Ngan, X. Q., Celina, S., Tanyeri, A., Gammon, M., Abrams, B., Fischer, L., & Peckham, S. (2021). Cleaning up our acts: Psychological interventions to reduce engine idling and improve air quality. *Journal of Environmental Psychology, 74*, Article 101587. https://doi.org/10.1016/j.jenvp.2021.101587

Abrams, D., Wetherell, M., Cochrane, S., Hogg, M. A., & Turner, J. C. (1990). Knowing what to think by knowing who you are: Self-categorisation and the nature of norm formation, conformity, and group polarisation. *British Journal of Social Psychology, 29*, 97–119. https://doi.org/10.1111/j.2044-8309.1990.tb00892.x

Bates, D. M., M ächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Bergquist, M., Nilsson, A., & Schultz, W. P. (2019). A meta-analysis of field-experiments using social norms to promote pro-environmental behaviors. *Global Environmental Change, 59*, Article 101941. https://doi.org/10.1016/j.gloenvcha.2019.101941

Bergquist, M., Thiel, M., Goldberg, M. H., & Van Der Linden, S. (2023). Field interventions for climate change mitigation behaviors: A second-order meta-analysis. *Proceedings of the National Academy of Sciences, 120*(13), Article e2214851120. https://doi.org/10.1073/pnas.2214851120

Bolderdijk, J. W., Gorsira, M., Keizer, K., & Steg, L. (2013). Values determine the (in) effectiveness of informational interventions in promoting pro-environmental behavior. *PLoS One, 8*(12), Article e83911. https://doi.org/10.1371/journal.pone.0083911

Burn, S. M., & Oskamp, S. (1986). Increasing community recycling with persuasive communication and public commitment. *Journal of Applied Social Psychology, 16*(1), 29–41. https://doi.org/10.1111/j.1559-1816.1986.tb02276.x

Cacioppo, J. T., & Petty, R. E. (1979). Effects of message repetition and position on cognitive response, recall, and persuasion. *Journal of Personality and Social Psychology, 37*(1), 97–109.

Cialdini, R. B., & Goldstein, N. J. (2004). Social influence: Compliance and conformity. *Annual Review of Psychology, 55*, 591–621. https://doi.org/10.1146/annurev.psych.55.090902.142015

Cialdini, R. B., Kallgren, C. A., & Reno, R. R. (1991). A focus theory of normative conduct: A theoretical refinement and reevaluation of the role of norms in human behavior. *Advances in Experimental Social Psychology, 24*, 201–234. https://doi.org/10.1016/S0065-2601(08)60330-5

Cialdini, R. B., Reno, R. R., & Kallgren, C. A. (1990). A focus theory of normative conduct: Recycling the concept of norms to reduce littering in public places. *Journal of Personality and Social Psychology, 58*(6), 1015–1026. https://doi.org/10.1037/0022-3514.58.6.1015

Department for Environment, Food & Rural Affairs. (2017). Air pollution in the UK 2016. https://uk-air.defra.gov.uk/assets/documents/annualreport/air_pollution_uk_2016_issue_1.pdf.

Deutsch, M., & Gerard, H. B. (1955). A study of normative and informational social influences upon individual judgment. *Journal of Abnormal and Social Psychology, 51*(3), 629–636. https://doi.org/10.1037/h0046408

Dogan, E., Bolderdijk, J. W., & Steg, L. (2014). Making small numbers count: Environmental and financial feedback in promoting eco-driving behaviours. *Journal of Consumer Policy, 37*(3), 413–422. https://doi.org/10.1007/s10603-014-9259-z

Eghbalnia, C., Sharkey, K., Garland-Porter, D., Alam, M., Crumpton, M., Jones, C., & Ryan, P. H. (2013). A community-based participatory research partnership to reduce vehicle idling near public schools. *Journal of Environmental Health, 75*(9), 14–19. Retrieved from https://www.jstor.org/stable/26329619.

Eichler, W. (2018). Pollution cut as signs prompt drivers to switch off engines. *Transport Network*. https://www.transport-network.co.uk/Pollution-cut-as-signs-prompt-drivers-to-switch-off-engines/14900.

European Environment Agency. (2022). Air quality in Europe 2022 (report no 05/2022). https://www.eea.europa.eu/publications/air-quality-in-europe-2022.

Festinger, L. (1954). A theory of social comparison processes. *Human Relations, 7*(2), 117–140. https://doi.org/10.1177/001872675400700202

Frick, J., Kaiser, F. G., & Wilson, M. (2004). Environmental knowledge and conservation behavior: Exploring prevalence and structure in a representative sample. *Personality and Individual Differences, 37*(8), 1597–1613. https://doi.org/10.1016/j.paid.2004.02.015

Hothorn, T., Bretz, F., & Westfall, P. (2008). Simultaneous inference in general parametric models. *Biometrical Journal, 50*(3), 346–363. https://doi.org/10.1002/bimj.200810425

Hussey, D. (2023). Exploring the impact of actionable guidance & feedback on pro-environmental behaviors, climate anxiety, and environmental efficacy. *Proceedings of the Human Factors and Ergonomics Society - Annual Meeting, 67*(1), 1735–1740. https://doi.org/10.1177/21695067231195912

Idling Action London. (2022). Research for Idling action on campaign strategies and messaging- final report. https://static1.squarespace.com/static/6257f80d5ce8e000521c958c/t/62a3600be437aa7258e19020/1655128968896/Idling+Action+research_final.pdf.

Jans, L. (2021). Changing environmental behaviour from the bottom up: The formation of pro-environmental social identities. *Journal of Environmental Psychology, 73*, Article 101531. https://doi.org/10.1016/j.jenvp.2020.101531

Kaiser, F. G., & Fuhrer, U. (2003). Ecological behavior's dependency on different forms of knowledge. *Applied Psychology, 52*(4), 598–613. https://doi.org/10.1111/1464-0597.00153

Keizer, K., & Schultz, P. W. (2018). Social norms and pro-environmental behaviour. In L. Steg, & J. I. M. de Groot (Eds.), *Environmental psychology: An introduction* (2nd ed., pp. 179–188). John Wiley & Sons Ltd. https://doi.org/10.1002/9781119241072.ch18.

Kushwah, A., & Oshiro Caldeira, L. K. (2025). Beyond the drive: Tackling idling energy consumption of heavy-duty battery electric vehicle. In *2025 IEEE PES grid edge technologies conference & exposition*. https://doi.org/10.1109/GridEdge61154.2025.10887490

Lalot, F., Imada, H., Hopthrow, T., & Abrams, D. (2025). Driving change: A scoping review of psychological interventions to reduce engine idling and air pollution. *Journal of Environmental Psychology, 106*, Article 102691. https://doi.org/10.1016/j.jenvp.2025.102691

Lede, E., Meleady, R., & Seger, C. R. (2019). Optimizing the influence of social norms interventions: Applying social identity insights to motivate residential water conservation. *Journal of Environmental Psychology, 62*, 105–114. https://doi.org/10.1016/j.jenvp.2019.02.011

Lorenzoni, I., Nicholson-Coleb, S., & Whitmarsh, L. (2007). Barriers perceived to engaging with climate change among the UK public and their policy implications. *Global Environmental Change, 17*(3–4), 445–459. https://doi.org/10.1016/j.gloenvcha.2007.01.004

Mahmood, L., Abrams, D., Meleady, R., Hopthrow, T., Lalot, F., Swift, H., & Van de Vyver, J. (2019). Intentions, efficacy, and norms: The impact of different self-regulatory cues on reducing engine idling at long wait stops. *Journal of Environmental Psychology, 66*, Article 101368. https://doi.org/10.1016/j.jenvp.2019.101368

Mahmoudi, S., Peck, S., Smith, K. B., Kelly, K., & Madden, G. J. (2025). Effect of dynamic social norm messaging on intent to idle. *Journal of Environmental Psychology, 105*, Article 102635. https://doi.org/10.1016/j.jenvp.2025.102635

Medway Council. (2024). Air quality action plan 2024-2029. https://www.medway.gov.uk/downloads/file/7339/medway_air_quality_action_plan_2024_draft.

Mehdipour, H., Prokosch, M., Williams, D., Thomas, A. H., Seymour, B., Conley, J., & von Meding, J. (2024). The importance of belonging: Reflections on a participatory

action research project in Jacksonville, Florida. *Disaster Prevention and Management: An International Journal*. https://doi.org/10.1108/DPM-01-2024-0038

Meleady, R., Abrams, D., Van de Vyver, J., Hopthrow, T., Mahmood, L., Player, A., Lamont, R., & Leite, A. C. (2017). Surveillance or self-surveillance? Behavioral cues can increase the rate of drivers' pro-environmental behavior at a long wait stop. *Environment and Behavior, 49*(10), 1156–1172. https://doi.org/10.1177/0013916517691324

Mendoza, D. L., Bayles, M., Contreras, J. R., Bares, R., Olson, C. S., Crosman, E. T., & Forrest, R. T. (2022). Idle-free campaign survey results and idling reductions in an elementary school. *Vehicles, 4*(3), 865–902. https://doi.org/10.3390/vehicles4030048

Mendoza, D. L., Benney, T. M., Bares, R., Fasoli, B., Anderson, C., Gonzales, S. A., Crosman, E. T., Bayles, M., Forrest, R. T., Contreras, J. R., & Hoch, S. (2022). Air quality and behavioral impacts of anti-idling campaigns in school drop-off zones. *Atmosphere, 13*(5), 706. https://doi.org/10.3390/atmos13050706

Nolan, J. M., Schultz, P. W., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2008). Normative social influence is underdetected. *Personality and Social Psychology Bulletin, 34*(7), 913–923. https://doi.org/10.1177/0146167208316691

Nordhoff, S. (2024). Resistance towards autonomous vehicles (AVs). *Transportation Research Interdisciplinary Perspectives, 26*, Article 101117. https://doi.org/10.1016/j.trip.2024.101117

Osbaldiston, R., & Schott, J. P. (2012). Environmental sustainability and behavioral science: Meta-analysis of proenvironmental behavior experiments. *Environment and Behavior, 44*(2), 257–299. https://doi.org/10.1177/0013916511402673

Petty, R. E., & Cacioppo, J. T. (1986). The elaboration likelihood model of persuasion. *Advances in Experimental Social Psychology, 19*, 123–205. https://doi.org/10.1016/S0065-2601(08)60214-2

Player, A., Abrams, D., Van de Vyver, J., Meleady, R., Leite, A. C., Randsley de Moura, G., & Hopthrow, T. (2018). "We aren't idlers": Using subjective group dynamics to promote prosocial driver behavior at long-wait stops. *Journal of Applied Social Psychology, 48*(11), 643–648. https://doi.org/10.1111/jasp.12554

Rämä, P., & Kulmala, R. (2000). Effects of variable message signs for slippery road conditions on driving speed and headways. *Transportation Research Part F: Traffic Psychology and Behaviour, 3*(2), 85–94. https://doi.org/10.1016/S1369-8478(00)00018-8

Rumchev, K., Lee, A., Maycock, B., & Jancey, J. (2021). Reducing car idling at primary schools: An intervention study of parent behaviour change in Perth, Western Australia. *Health Promotion Journal of Australia, 32*(3), 383–390. https://doi.org/10.1002/hpja.381

Schultz, P. (2014). Strategies for promoting proenvironmental behavior: Lots of tools but few instructions. *European Psychologist, 19*(2), 107–117. https://doi.org/10.1027/1016-9040/a000163

Schultz, P. W., Khazian, A. M., & Zaleski, A. C. (2008). Using normative social influence to promote conservation among hotel guests. *Social Influence, 3*(1), 4–23. https://doi.org/10.1080/15534510701755614

Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2007). The constructive, destructive, and reconstructive power of social norms. *Psychological Science, 18*(5), 429–434. https://doi.org/10.1111/j.1467-9280.2007.01917.x

Seyranian, V., Sinatra, G. M., & Polikoff, M. S. (2015). Comparing communication strategies for reducing residential water consumption. *Journal of Environmental Psychology, 41*, 81–90. https://doi.org/10.1016/j.jenvp.2014.11.009

Shi, J., & Smith, S. W. (2016). The effects of fear appeal message repetition on perceived threat, perceived efficacy, and behavioral intention in the extended parallel process model. *Health Communication, 31*(3), 275–286. https://doi.org/10.1080/10410236.2014.948145

Sigurjonsdottir, S. S., Elnes, A. K., & Couto, K. C. (2022). Turn off your engine: Reducing idling amongst professional truck drivers. *Transportation Research Interdisciplinary Perspectives, 15*, Article 100654. https://doi.org/10.1016/j.trip.2022.100654

Skilbeck, C., Tulips, J., & Ley, P. (1977). The effects of fear arousal, fear position, fear exposure, and sidedness on compliance with dietary instructions. *European Journal of Social Psychology, 7*(2), 221–239. https://doi.org/10.1002/ejsp.2420070208

Sommet, N., & Morselli, D. (2017). Keep calm and learn multilevel logistic modeling: A simplified three-step procedure using Stata, R, Mplus, and SPSS. *International Review of Social Psychology, 30*(1). https://doi.org/10.5334/irsp.90

Spears, R. (2021). Social influence and group identity. *Annual Review of Psychology, 72*, 367–390. https://doi.org/10.1146/annurev-psych-070620-111818

Terry, D. J., & Hogg, M. A. (1996). Group norms and the attitude-behavior relationship: A role for group identification. *Personality and Social Psychology Bulletin, 22*(8), 776–793. https://doi.org/10.1177/0146167296228002

Terry, D. J., Hogg, M. A., & White, K. M. (1999). The theory of planned behaviour: Self-identity, social identity and group norms. *British Journal of Social Psychology, 38*(3), 225–244. https://doi.org/10.1348/014466699164149

Transport Research Laboratory. (2021). Idling action research - Review of emissions data. *TRL*. https://trl.co.uk/news/trl-supports-engine-off-campaign.

Trott, C. D., Even, T. L., & Frame, S. M. (2020). Merging the arts and sciences for collaborative sustainability action: A methodological framework. *Sustainability Science, 15*, 1067–1085. https://doi.org/10.1007/s11625-020-00798-7

Turner, J. C., Hogg, M. A., Oakes, P. J., Reicher, S. D., & Wetherell, M. (1987). *Rediscovering the social group: A self-categorization theory*. Oxford: Blackwell.

UN Environment Programme. (2024). Annual report 2024. https://www.unep.org/resources/annual-report-2024.

Van de Vyver, J., Abrams, D., Hopthrow, T., Purewal, K., de Moura, G. R., & Meleady, R. (2018). Motivating the selfish to stop idling: Self-interest cues can improve environmentally relevant driver behaviour. *Transportation Research Part F: Traffic Psychology and Behaviour, 54*, 79–85. https://doi.org/10.1016/j.trf.2018.01.015

Van Vugt, M. (2001). Community identification moderating the impact of financial incentives in a natural social dilemma: Water conservation. *Personality and Social Psychology Bulletin, 27*(11), 1440–1449. https://doi.org/10.1177/01461672012711005

Vandenbergh, M. P., Dietz, T., & Stern, P. C. (2011). Time to try carbon labelling. *Nature Climate Change, 1*, 4–6. https://doi.org/10.1038/nclimate1071

Zeileis, A., & Hothorn, T. (2002). Diagnostic checking in regression relationships. *R News, 2/3*, 7–10. https://journal.r-project.org/articles/RN-2002-018/RN-2002-018.pdf.