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CAN CAR ENGINE IDLING BE REDUCED USING PERSUASIVE MESSAGES?

Canterbury Air and Noise Pollution Experiment 2018-19

Professor Dominic Abrams, Dr Tim Hopthrow, Hirotaka Imada,
Hilal Ozkececi, Dr Fanny Lalot and Dr Anne Templeton

THE AUTHORS

All authors and research collaborators are members of Grouplab at the University of Kent, School of Psychology. Dominic Abrams is Director of the Centre for the Study of Group Processes, Tim Hopthrow is the Faculty of Social Sciences Associate Dean of Research and Innovation, Fanny Lalot is a Research Associate. Hilal Ozkececi and Hirotaka Imada are PhD students at the University of Kent. Anne Templeton is now a lecturer in psychology at Edinburgh University.

ACKNOWLEDGEMENTS

We are grateful to Richard Griffiths, Kelly Haynes and Ruth Goudie at Canterbury City Council for their advice and help with the practical planning of this research. Professor Stephen Peckham and Dr Ashley Mills were involved in discussions that helped us to procure, install and use the air quality monitoring equipment, supported by a University of Kent grant to Anne Templeton in the School of Psychology, working with Dominic Abrams and collaborating with Stephen Peckham.

The following were directly involved in the planning of the research: Dr Rose Meleady (University of East Anglia), Dr Julie Van de Vyver (Durham University), all members of Grouplab at the School of Psychology, University of Kent.

The following devoted significant amounts of time to observational data collection and coding: Sarah Warbis, Dominic Sandiford, Zoe Abrams, Alice Abrams, Ben Steeden, Emily Fell, S Celina, Xue Qing Ngan, Sophie Drysdale, Riska Dewi, Lilian Fischer, Molly Gammon, Ben Abrams, Ana Leite. Part of the data collection for this project contributed to Sarah Warbis' MSc dissertation.

Technical support for the use of noise monitoring equipment was provided by Adam Britcher in the School of Psychology.

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OFF
PUSH

/ SUMMARY

Engine idling is one of the major contributors to pollution, especially in densely populated urban areas. Persuading drivers to turn off their engines can potentially reduce both air pollution and noise pollution, both of which are important bio-social stressors. Based on social psychological theories and methods, this project assessed the effectiveness of various road sign messages designed to persuade drivers to turn off their engines whilst waiting for trains to pass a level crossing.

Monitors placed near level crossings at two locations in Canterbury (St Dunstans and St Stephens) measured background levels of air pollutant concentrations (ie, NO_2, $PM_{2.5}$, and O_3 levels) and noise levels. Air quality values exceeded the national and EU recommended threshold values on the majority of days recorded, indicating a meaningful risk to those in the vicinity during these periods.

Noise levels also exceeded comfort thresholds for between a 20% and 30% of the time. Three different intervention messages were displayed for one week each at of the two different locations across a five-week period in the summer of 2018. Train crossings lasted approximately two minutes on average. While the barriers were down, researchers recorded whether each vehicle in the queue had its engine idling, and also recorded other factors that might affect engine idling (weather conditions, number of people in the car, etc.). Compared with a baseline when no messages were displayed, the three intervention messages reliably increased compliance to switch off engines by between 16 and 38 percent.

The most effective message was designed to motivate drivers to stop their engines by reminding them of their responsibility. These findings indicate that the strategic use of carefully formulated messages via road signage can be a highly cost effective tool for reducing engine idling and hence reducing the harm to air quality, health and well-being in Canterbury.

BACKGROUND

1 Traffic and air pollution

Air pollution is a major threat to health and well-being especially in urban areas. The European Environment Agency recently reported that amongst EU countries, air pollution caused more than half a million deaths per year and a significant increase in health expenses (EEA, 2016).

Amongst a variety of sources of air pollutants in the urban areas, traffic is one of the major contaminators. Motor vehicles traffic produces several air pollutants, amongst which NO_2 (nitrogen dioxide), O_3 (trioxygen or ozone), and $PM_{2.5}$ (particulate matter with a diameter of less than 2.5 micrometres) are especially dangerous for health. For example, previous scientific research found that outdoor exposure to high levels of NO_2 was associated with higher risk of death by coronary heart disease, accounting for 6% of the total number of deaths (Maheswaran et al., 2005). Moreover, particulate matter and NO_2 have a particularly damaging effect on young children (Sharma & Kumar, 2018). As it is, between 2014 and 2016, 74-85% of urban population were exposed to levels of NO_2 above the threshold set by World Health Organisation, and the percentage reached 98% for O_3 (EEA, 2018).

Even if pollutants come from many factors, road traffic is one of the most important source, accounting for example for 39% of the NO_2 emissions in EU countries (EEA, 2018) and 24% of greenhouse gas emissions (including CO_2 and O_3) in the UK (Defra, 2016, 2018). This often ends up with reaching and exceeding the thresholds (especially on roadsides; Defra, 2018), posing a risk of serious health and environmental issues.

2 Traffic noise

Noise from traffic is another important issue. Environmental noise is associated with a wide range of health problems such as hypertension (Jarup et al., 2008) as well as negative psychological effects such as psychological distress, oversensitivity towards auditory stimuli, and a wide range of cognitive impairments (Clark & Stansfeld, 2007; Stansfeld & Matheson, 2003). Different outcomes have been associated with different thresholds of noise, and evidence shows that noise starts to be problematic at 65-70 decibels (dB). Noise above 65-70dB indeed raises by up to 50% the probability of developing a heart disease and hypertension (Babisch, 2000). Chronic exposure to workplace noise levels around 70dB might damage health and lead to auditory disorders (Sjödin, Kjellberg, Knutsson, Landström, & Lindberg, 2012), and is psychologically harmful. Finally, regular exposure to noise at levels from 85dB upwards has negative influences on hearing ability, and the hazard swiftly surges once noise levels reach 90dB (HSE, 2005). Heavy traffic usually produces a background noise around 80-90dB. Research on effects of traffic noise has revealed that exposure to transportation noise (including aircraft and road traffic) led to annoyance and impaired sleep quality, particularly amongst people aged 50-56 (Miedema & Voss, 2007). Traffic noise is also an important risk factor for cardiovascular diseases (Babisch, 2000). A 5dB increase in road traffic noise levels was associated with a 30% likelihood increase of hypertension (Bluhm & Eriksson, 2011). Amongst people working nearby the road, exposure to traffic noise significantly interfered with the daily activities such as communication and led to increased annoyance (Pathak, Tripathi, & Mishra, 2008). Therefore, especially in urban areas, excessive traffic noise is physically and psychologically harmful.

3 Practices to enhance air quality

Various schemes and legal actions have been applied in many European countries in order to improve air quality, and the UK is no exception. Different actions, however, are not equally effective (see for example Holman, Harrison, & Querol, 2015). In this section, we review some of the most common strategies implemented in different cities within the UK, including Canterbury.

3.1 Air quality management in the UK

Following the adoption of national standards of air quality, local authorities are now responsible for assessing air quality and make sure they meet the national air quality objectives. Regions falling short have to declare an Air Quality Action Plan (hereinafter, AQAP) and develop specific action plans in order to meet the standards (Defra, 2015). Most of the time, these plans include: getting rid of old and polluting vehicles, encouraging cleaner or even electric vehicles, decreasing the amount of traffic in general, and encouraging the use of public transports and cycling.

One action involves defining Low Emission Zones (LEZ). “Clean” vehicles (under certain emission rates) can freely circulate in these zones, whereas polluting vehicles (above those rates) need to pay a fee to enter, or are banned altogether. Such LEZ have been set up, so far, in Norwich and London (which will be introducing an Ultra Low Emission Zone in the near future; TfL, 2019). Despite being relatively rare in the UK so far, LEZ are much more common in Europe and already exist in more than 200 cities. However, research on the effectiveness of LEZ has not yet demonstrated substantial improvements in air quality overall (Holman et al., 2015). In London specifically, particular matter concentrations showed a 3% decrease (against a 1% decrease outside LEZ) and NO_2 concentrations did not significantly decrease (Ellison, Greaves, & Hensher, 2013). So far, evidence has not clearly demonstrated any short term benefits for health either; for example, no change in respiration quality could be seen amongst 8-9 year old children living near LEZ during the past 3 years (Wood et al., 2015). However, the available data do not address how wide or localised any effects might be, nor what a suitable time frame is for evaluating the longer term gains from these initiatives. In addition to punishing polluting vehicles, other cities have chosen to reward clean vehicles. For example, Cambridge offers fees reduction for low emission vehicles.

Some zones heavily impacted by traffic congestion also apply an entry fee regardless of the characteristics of the vehicle. The Congestion charge zone in London is one example. Assessment of this scheme showed that it was effective in diminishing congestion, thereby leading to (relatively minor) reductions in air pollutant concentrations and increase of life expectancy (Tonne, Beevers, Armstrong, Kelly, & Wilkinson, 2008). In the same vein, Manchester has reduced the availability of free parking in parking lots to discourage private car use.

Other air quality management plans are designed to decrease the use of motor vehicles and provide practicable alternatives. For example, Cambridge, Manchester, and Edinburgh are trying to develop and encourage better public transport; they also take opportunities to open new cycle lanes and create campaigns to promote cycling and walking. Edinburgh and Cambridge plan to install a number of electric charging points to encourage electric vehicles. In this respect, they follow Manchester, whose city council successfully adopted a solar-powered electric car for their officers' trips around the City, and developed a network of charging stations for electric vehicles. Edinburgh additionally plans to implement regular vehicle-free days and to invest towards the use of electric buses.

Because air pollution is never evenly distributed over any locality, many cities have tried to monitor air quality locally in order to identify the zones most problematic. These zones, called Air Quality Management Areas (AQMAs) represent critical zones in terms of air pollutants concentrations for which action is most seriously needed. Importantly, changes in pollutant concentrations in such zones indicate that the ongoing action plans are having an effect. For example, Edinburgh observed significant decreases in NO_2 and particulate matters in their AQMA as a result of the changes they introduced.

CONTINUED OVERLEAF

BACKGROUND (CONT)

3.2 Air quality management in Canterbury

In compliance with the Local Air Quality Management framework, Canterbury had to implement an Air Quality Action Plan. The latest plan was adopted in 2018 to cover 2018-2023 (Canterbury City Council, 2018). It recognises NO_2 emissions exceeding the national threshold and identifies several AQMAs, which have unfortunately expanded in recent years, from "parts of the A28 at Broad Street/Military Road" in 2006 to the addition of "two small additional areas of Broad Street and Wincheap" in 2011, to the most recent addition of small areas of Old Dover Rd, New Dover Road, Lower Chantry Lane, Military Road and Rheims Way in 2018. Wincheap currently shows the highest level of roadside concentration of NO_2 whereas St Peter's Roundabout suffers from the highest overall concentration of NO_2 (roadside + background). Figure 1 below illustrates the current state of AQMA in Canterbury and possible extensions (note that St Dunstans is within the possible amendment to the boundary but St Stephens is not). The first measure and action point in the Air Quality Action Plan is to address engine idling through campaigns, enforcement and other means. This project directly addressed one possible avenue for action.

As in other cities, the most prominent source of air pollution in Canterbury is road traffic. Indeed, cars contribute to the largest proportion (45%) of NO_2 emissions where NO_2 levels are above the annual limit. Current strategies to tackle pollution problems include provision of improved cycling routes and introduction of Park and Pedal Scheme around the Wincheap area – which would enable cycling to the city centre – and improving the conditions of public transport to decrease car use. The most recent AQAP lists new actions, including: introduction of electric vehicle charging points at main car parks, promotion of more active modes of transport, and use of intelligent traffic system to reduce traffic congestion. Several actions are also specifically targeting engine idling behaviour, notably educational campaigns in primary schools to reduce idling in the area surrounding the schools, and more general awareness campaign amongst car and taxi drivers. The introduction of a penalty for idling is envisioned as a second step if the prevention campaigns are not effective enough.

Canterbury AQAP primarily focuses on levels of NO_2 and aims to reduce it to below the legal threshold of annual mean of 40µg/m^3. Level of $PM_{2.5}$ is currently not regulated at the national level, but the AQAP aims nonetheless to reduce it as much as reasonably practicable. Moreover, the AQAP anticipates that by 2025 the recommended limit will be the WHO threshold of 10µg/m^3. This target is as aspired to in the 2019 Clean Air Zones in five major UK cities. Similarly, level of O_3 is not the responsibility of the council under LAQM scheme, rather the concern of national authorities.

Figure 1: Existing AQMA and possible extensions to AQMA in Canterbury (Copyright Canterbury City Council Air Quality Action Plan 2018-2023).

However, 8-hour mean levels over 100µg/m^3 are considered hazardous and because O_3 levels closely track temperature levels, they pose a greater threat in warmer parts of the country such as Canterbury. Actions taken in order to reduce NO_2 concentration are anticipated to improve $PM_{2.5}$ and O_3 concentrations as well, although the latter are not the main focus.

Air quality monitors are increasingly being deployed to assess the concentration of the various pollutants, and the efficacy of the actions undertaken. For example, a continuous NO_2 air quality monitoring station is in place in Military Road. For 2016, the monitor calculated an annual average of 33µg/m^3, which is below the legal threshold. Another monitor, located at Chaucer School, records O_3 levels in addition to NO_2. A number of nitrogen dioxide diffusion tubes are located across Canterbury District that provide low-cost monitoring of average air quality. These are mainly placed near main roads and schools in the AQMAs, Whitstable and Herne Bay and at level crossings in Canterbury. However, the diffusion tubes are not sensitive to the hourly variations (eg peaks during day time, very low levels at night) and therefore do not convey the extent of exposure to drivers, pedestrians and residents when they are most likely to be affected.

4 Engine idling, air and noise pollution

To summarise, motor vehicles are responsible for an important proportion of air pollution and noise levels. More specifically, engine idling is particularly dangerous in terms of air pollution because the exhaust emissions do not easily disperse. Researchers estimate that engine idling alone accounts for 1.6% of CO_2 emissions (Carrico, Padgett, Vandenbergh, Gilligan, & Wallston, 2009). It also results in additional emission of particulate matter and NO_2, which reduce air quality, and as a result is a direct cause of respiratory and heart problems (Shancita et al., 2014). Finally, engine idling significantly increases the noise levels in the environment (Pal & Sarkar, 2012).

Hence, reducing rates of engine idling could contribute to reduction in both air and noise pollution levels. Importantly, engine idling is the result of behavioural decisions that are amenable to immediate influence. The potential costs of such influence are relatively minor, particularly considering the substantial gains that might be achieved. In the present project, we developed interventions based on psychological theory and research which were designed to encourage different motivations for drivers to consider turning off their idling engine.

THE PRESENT INTERVENTION

Previous research in St Dunstans, Canterbury, demonstrated the feasibility of using persuasive messages to affect engine idling rates. A series of small-scale field experiments (Meleady et al., 2017; Player et al., 2018; Van de Vyver et al., 2018) showed that it was possible to reduce engine idling by up to 25%.

However, these experiments relied on the presence of a research assistant standing stationary near the level crossing and holding the sign affixed to a stationary pole. It is possible that the presence of a person holding the sign could have altered drivers' behaviour, regardless of the messages used. Moreover, the messages were only visible during the data collection time periods; in other words, the design did not allow for a repetitive exposure to one message, more likely to induce the creation of new habits for the drivers passing in front of the sign regularly. A further limitation is the studies only involved a few hundred vehicles and were all conducted in just one location. Therefore we do not know how well the effects of the signs might generalise across different locations.

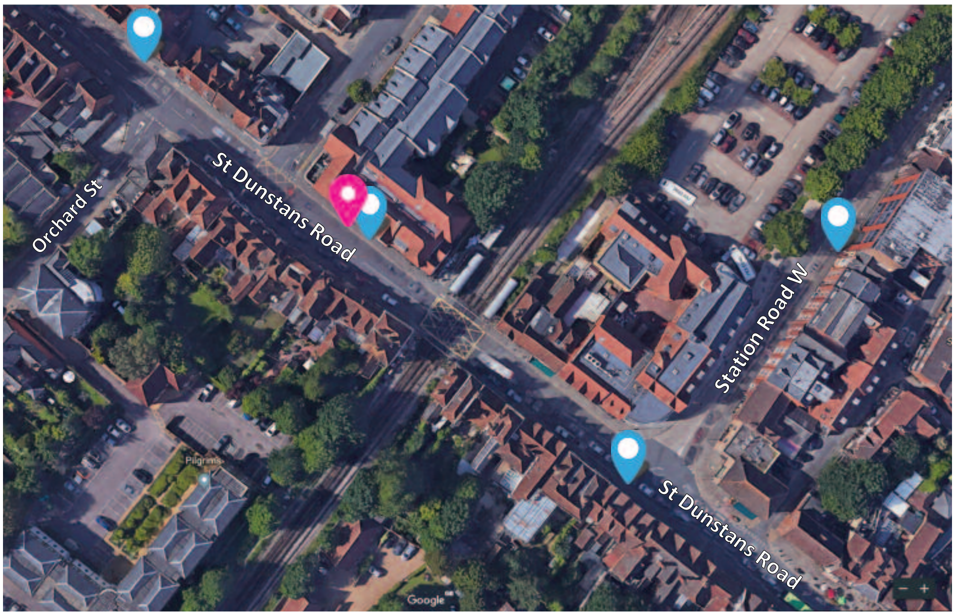

Figure 2: St Dunstans Road. The blue pins indicate the position of the four road signs used for the experiment. The pink pin indicates the position of the air and noise monitor.

Figure 3: St Dunstans level crossing with the "Responsibility" intervention sign.

1 Objectives

To address these limitations, we conducted a new and much larger experiment ensuring that messages would effectively reduce engine idling when *(a)* fixed on a regular street pole instead of being held by a person and *(b)* displayed continuously for several days. In the present project we conducted new air quality and noise level monitoring near level crossings to ascertain the extent of the problem. We tested the behavioural effects on engine idling when displaying three types of messages, each of which had proven effective in the smaller scale studies. This meant that we would be able to test both whether the signs remained effective even when not being held by a person, and also we could directly compare how effective each message is. In summary, on both sides of the level crossings at St Dunstans and St Stephens we observed drivers' idling behaviour when the level crossing barriers dropped for three one-hour time periods in each day of observation.

2 Method

Our sample consisted of 6,528 vehicles traveling across two level crossings in Canterbury in the summer of 2018. The testing period ran from the first week of July to the first week of August (ie, five weeks in total). No sign was put up during the first week, which served as the baseline and allowed to assess the average rate of engine idling behaviour prior to the intervention.

CONTINUED OVERLEAF

THE PRESENT INTERVENTION (CONT)

During the following four weeks, three different road signs were put up, each one for a week, and they were swapped every Monday. The signs at St Dunstans and St Stephens were never the same during any particular week, and they were presented in a rotating sequence. The testing period ran from every Tuesday to Thursday at three time intervals each day: 9-10am, 1-2pm, and 5-6pm. During level-crossing barrier down times, two researchers manually recorded engine idling for all vehicles from the barrier to the end of the queue of traffic (or as many as possible before the barriers were raised).

In addition to the key variable, which was whether the driver turned off their engine, we recorded the following information: type of vehicle (car, bus, lorry, motorbike, van/service vehicle, or taxi), number of passengers in the vehicle, whether any children were in the car, and whether any windows were open. We also recorded the duration of the barrier drop and the position in the queue of each vehicle. As these factors did not qualify the main findings, we do not discuss them further in this report. Separate automated recording was conducted to monitor air quality and noise levels.

2.1 Locations

The experiment took place at St Dunstans road level-crossing[1] and St Stephens road level-crossing[2]. Multiple assistants helped with data collection, and almost all collected data from all four positions (2 locations × 2 directions) to guard against any coder biases. At any one measurement period, two researchers were at each location, one on each side of the crossing, to record the drivers' behaviour.

2.1.1 St Dunstans road

Figure 2 shows locations of road signs and monitors for air and noise levels at St Dunstans road level crossing. The following poles were used for placing the monitors: JH010 opposite Londis, pole next to H300 hydrant sign opposite The Unicorn, CCTV post next to KentUnilet.com, and SME003. Figure 3 illustrates the level crossing location with one of the intervention signs.

2.1.2 St Stephens road

Figure 4 shows locations of road signs and monitors for air and noise levels at St Stephens road level crossing. The following poles were used for placing the monitors: lamppost SKZ017, lamppost next to stop sign SKZ520, lamppost next to SKZ521, and lamppost roughly 50m away from the level-crossing. Figure 5 illustrates the level crossing location.

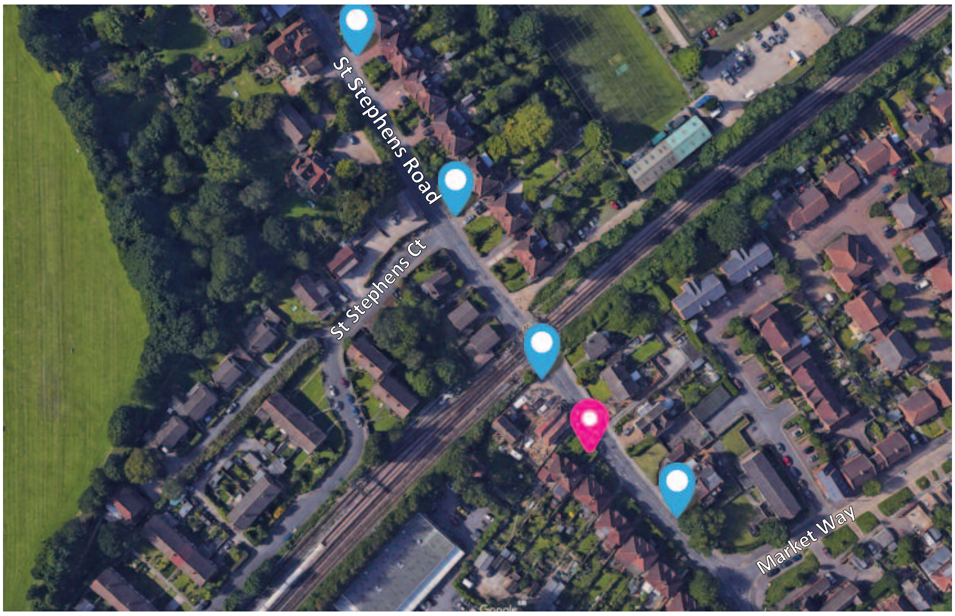

Figure 4: St Stephens Road. The blue pins indicate the position of the four road signs used for the experiment. The purple pin indicates the position of the air and noise monitor.

Figure 5: St Stephens level crossing.

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[1] Map: https://goo.gl/maps/Gw9yBe7x9U62
[2] Map: https://goo.gl/maps/C3c1dxWKFX62

2.2 Air pollution levels

EarthSense Zephyr Air Quality Sensors were used to measure concentrations of air pollution. The sensors measured temperature, humidity, and the level of NO_2, O_3, and $PM_{2.5}$. Each sensor is calibrated by the manufacturer by co-locating it with a local authority reference site, giving a stated accuracy of +/-5 µg/m³ for NO_2 and $PM_{2.5}$, and +/-8 µg/m³ for O_3. For example the Zephyr has been calibrated against an Automatic and Urban and Rural Network (AURN) site at Leicester University (part Defra's network)[3].

The measurement is not intended to be used to infer annual means for the studied locations nor to contrast pollution levels with those recorded for local authority air quality management activities and associated regulatory limits. The purposes of the measurement are to provide context for the potential impact of the behavioural intervention, to understand how pollution at the intervention sites varies with time, to consider whether dynamic changes are likely to have an impact on air quality, and thus to inform about the potential value of this type of intervention.

We do however reference annual regulatory limits for $PM_{2.5}$ and NO_2 and adopt them as convenient thresholds against which to report air pollution severity. Longer duration measurements could be used to inform those locations' situation vis-à-vis annual regulatory compliance, but the data used in this report serve principally as an indicative tool to assess severity against values that are in common parlance.

Various moment-to-moment and day-to-day variations in factors such as weather and wind cause changes in levels of pollutants, and these factors are not the focus of this report. However, the sensors did measure temperature (in degrees Celsius) and humidity (in percentage). The sensors were attached to a lamppost on the side of the road where traffic was heading towards the level crossings, roughly two meters above the ground, and approximately 30 meters from the level crossings. It is for example visible on the lamppost on Figure 3.

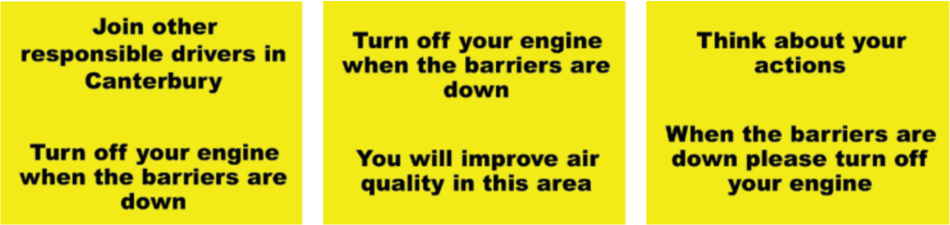

Figure 6: The three intervention messages used in the experiment, from left to right: Responsibility, Effectiveness, and Reflect.

2.3 Noise level

The CEM DT-8852 Digital Sound Level Meter was used to measure noise level. Accuracy is +/- 1.4 dB, and frequency range is 31.5Hz–8KHz. The sensor was secured on a tripod on the pavement, positioned underneath the air pollution meter.

2.4 Intervention road signs

The intervention signs were printed on 60cm × 45cm, black text over yellow background, designed to stand out against white road signs already present. They were fixed to lampposts, 2.5 metres above the ground. Three different intervention signs, displaying different messages, were used. The messages were drawn from previous research (Meleady et al., 2017; Player et al., 2018) with respect to psychological theories of motivation and social influence. The messages, illustrated in Figure 6, are the following:

- **Responsibility:** this message aims to make drivers aware that they should conform to norms set by others who are considered 'responsible' (ie socially approved) by switching off their engine;
- **Effectiveness:** this message highlights drivers' ability to exert control over air quality by stopping their own engines;
- **Reflect:** this message encourages drivers to consider their actions (and implicitly to decide for themselves whether it is approriate to switch off their engine).

3 Results

Since air pollution and noise levels can differ from one place to another, and because St Dunstans is, but St Stephens is not in the AQMA, we present the descriptive results separately for St Dunstans and St Stephens. We begin by presenting the air quality and noise level data at the two locations.

3.1 Air quality

Higher levels of air pollution are related to more negative health outcomes for both the conditions of average annual (chronic) exposure as well as episodic peak exposures (eg hourly peaks, or acute levels). We are interested in the effect of dynamic changes on pollution generating behaviour, and the likely health burden. Table 1 shows the average levels of NO_2, O_3 and $PM_{2.5}$ across the five-week period of the trial. These average levels do not necessarily reflect the chronic levels of exposure of people in each area because there is considerable variation owing to time of day, temperature, weather conditions and so forth. Figure 7 illustrates the hourly average level of pollutants over the course of a 24-hour period (just one period is shown for illustration, July 5th, which was part of the baseline measurement period). Also shown are the national thresholds for annual averages (chronic levels) for the different pollutants, to provide context.

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[3] A Zephyr that has been co-located with a unit similar to that used in Military Road, Canterbury, at the Ospringe 2 site (Swale Council) yields closely matching results. We are currently planning a further study to compare the measurement with Canterbury City Council's own methods at a co-located site in Canterbury.

THE PRESENT INTERVENTION (CONT)

The figure illustrates that relevant public exposures are not characterised well by annual average thresholds, since there is a large degree of hourly variation. We know that negative health outcomes are correlated with periods of peak exposure as well as chronic levels, so it is prudent to ask the question: how likely it would be that any individual encounter levels that exceed recommended short-term (ie hourly) thresholds during the experimental period and within any one hour period in the two zones (St Stephens, St Dunstans)?

Air pollution levels were recorded every 10 seconds. The data refer to measurements taken on Tuesdays to Fridays throughout the period of the trial. Data from Mondays and weekends are not reported because of the different traffic patterns and because signs were changed over during Mondays. For NO_2, Defra Committee on the Medical Effects of Air Pollutants (COMEAP) uses a 200 g/m^3 peak threshold to determine likely impact over time. For O_3, Defra uses an 8-hour rolling average. Table 2 shows, for each location, the average number of times that NO_2 exceeded the 200 g/m^3 peak each 24-hour period, and the 8-hour rolling average for O_3. Table 3 shows the detail of the evidence on particulate matter $PM_{2.5}$ (25 g/m^3 and 10 g/m^3). Outside of daytime working hours, these areas have relatively few vehicles and pedestrians. Therefore, we assessed the proportion of daytime hours (which we defined as the periods from 7am to 7pm) in which levels of particulates were exceeded on each day of the trial.

Regarding the links with temperature and humidity, we noted that air pollution levels (all three pollutants) increased when temperature increased (positive correlation), and decreased when humidity decreased (negative correlation). All correlations are reported in Appendix 1.

3.1.1 NO_2 and O_3

Table 2 shows that pollutant concentrations of NO_2 typically exceeded the current recommended threshold three or more times per day in both locations. The level was exceeded on 16 out of the 20 days of the trial. We checked the number of different hours within the 7am-7pm period that these readings occurred and found that this ranged from 0 to 7.

The 8-hour running averages for O_3 reveal substantial variations (as shown by important standard deviations) and for example, for the six consecutive 8-hour periods starting at 7am until 12pm (lasting until 8pm) the averages were at or above 100 g/m^3 in one or both locations. The 24-hour rolling average is lower because levels drop substantially as the air cools overnight. However, throughout the 7am to 7pm period, levels are consistently high (mean levels for St Dunstans and St Stephens are 104.7 g/m^3 and 106.2 g/m^3, with standard deviations of 7.1 g/m^3 and 4.1 g/m^3, respectively).

3.1.2 $PM_{2.5}$ (at 25 g/m^3 and 10 g/m^3)

We focussed on $PM_{2.5}$ levels during day time hours when people are most likely to be exposed. In anticipation of the adoption of the lower $PM_{2.5}$ threshold in future, we report both the current threshold of 25 g/m^3 and also the lower level of 10 g/m^3. The average numbers of one-hour time intervals where the thresholds were exceeded are reported in Table 3.

Upper thresholds were exceeded more frequently in St Dunstans area, meaning that most hours during an average day people would be exposed to above-limit air pollution levels at least once. Data from St Stephens revealed that pollution levels typically exceeded their thresholds in about one in four hours between 7am to 7pm. In both St Dunstans and St Stephens, the lower thresholds were exceeded in every one of the 12 one-hour periods of the day.

Table 1: Means and standard deviations of NO_2, O_3, and $PM_{2.5}$ levels, over the five-week period.

	NO_2	O_3	$PM_{2.5}$
Mean	18.62	67.21	5.57
SD	18.37	51.55	4.56

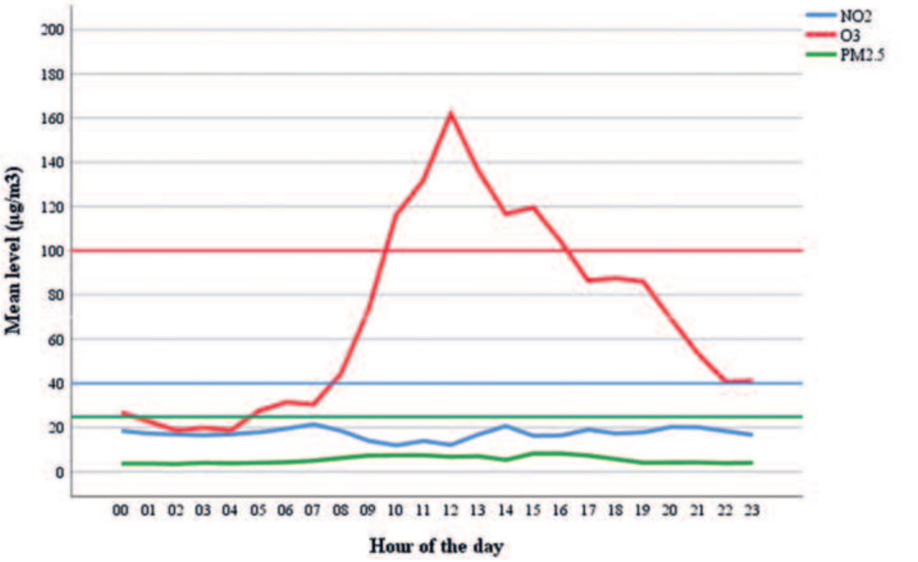

Figure 7: Hourly averages across both locations for NO_2, O_3, and $PM_{2.5}$ levels (July 5th 2018). Straight lines represent current legal annual average thresholds for each pollutant[4] (O_3: 100µg/m³, NO_2: 40µg/m³, $PM_{2.5}$: 25µg/m³).

Table 2: Descriptive statistics of NO_2 and O_3 concentrations. For O_3, the table presents 8-hour running averages. For NO_2, it presents average number of one-hour periods a day (out of 12) in which the recommended threshold of 200 g/m^3 was exceeded.

	St Dunstans		St Stephens	
	NO_2> 200 g/m^3 per day	$O_3$8-hour running average	NO_2> 200 g/m^3 per day	$O_3$8-hour running average
Mean	3.35	65.79	3.9	68.02
SD	5.17	28.12	4.18	28.40

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[4] Thresholds indicated at https://uk-air.Defra.gov.uk/air-pollution/uk-eu-limits, and www.gov.uk/government/publications/comeap-review-of-the-uk-air-quality-index

In summary, levels of air pollution showed peaks in short-term contributions to pollutant levels that exceed the hourly or 8-hour running average thresholds in both locations. These more detailed measures revealed that the recommended thresholds were typically exceeded within several hour periods during the daytime, hence inevitably exposing pedestrians and local inhabitants to hazardous conditions. The levels of particulates, which are clearly related to road traffic, exceeded the forthcoming threshold limits (10 g/m^3) every hour of the day.

3.2 Noise levels

We considered thresholds for different levels of potential harm from noise. We first report observed averages, then present results based on the 70dB threshold beyond which harmful consequences may arise for health and psychological well-being. We then also report evidence for the 80dB threshold (at which consequences become increasingly serious).

3.2.1 Average noise levels

Table 4 above illustrates the average levels of noise recorded at St Dunstans and St Stephens over the duration of the project. Values are averaged by hour. The results show that, on average, the sound level does not exceed 70dB.

Table 3: Average number of one-hour periods (out of 12) in which particulate matters levels exceeded their recommended (current and anticipated) threshold, and standard deviations.

	St Dunstans		St Stephens	
	PM$_{2.5}$ (25 g/m^3)	PM$_{2.5}$ (10 g/m^3)	PM$_{2.5}$ (25 g/m^3)	PM$_{2.5}$ (10 g/m^3)
Mean	7.95	12	3.40	12
SD	1.99	0	1.54	0

Table 4: Means and standard deviations of noise levels (in dB) recorded at St Dunstans and St Stephens level crossings, within each one-hour time interval across five weeks.

	St Dunstans				St Stephens			
	9am	1pm	5pm	Grand mean	9am	1pm	5pm	Grand mean
Hourly average	66.8	65.7	66.3	66.2	63.8	62.8	64.3	63.7
SD	5.93	6.23	5.80	6.01	7.80	8.41	7.36	7.86

Table 5: Percentage of time when noise level exceeded 70dB, presented by location and averaged within each one-hour time interval across five weeks.

	St Dunstans				St Stephens			
	9am	1pm	5pm	Grand mean	9am	1pm	5pm	Grand mean
Hourly average	32.4%	24.7%	24.1%	32.4%	20.8%	19.4%	22.9%	21.0%
SD	5.4%	5.1%	4.7%	5.4%	4.4%	3.0%	4.2%	4.4%

Table 6: Percentage of observed engine idling behaviour as a function of the type of vehicles, across all experimental conditions.

Vehicle type	Vehicles idling	Vehicles with engine off	Number of vehicles
Car	67.3%	32.7%	5,331
Bus	24.6%	75.4%	126
Lorry	79.2%	20.8%	101
Motorbike	50.0%	50.0%	34
Van/service	77.3%	22.7%	775
Taxi	59.0%	41.0%	161
Overall	67.6%	32.4%	6,528

3.2.2 Noise levels exceeding 70dB

The average noise levels conceal important within-hour variations. Hence, following the same logic as for pollution levels, we also looked at the proportion of time that sound peaked above 70dB and 80dB. Table 5 reports the percentage of time that noise levels exceeded 70dB. This level was exceeded more than a quarter of the time at St Dunstans and about a fifth of the time at St Stephens. This suggests that there is a meaningful likelihood in both locations.

3.2.3 Noise levels exceeding 80dB

We also examined the proportion of time that noise levels exceeded 80dB, ie, the threshold for directly harmful noise. To refine the measure, we considered the numbers of seconds, per hour, that the noise exceeded this threshold. As might be expected, noise levels typically exceeded 80dB only for a few seconds each hour (see details in Appendix 4). Across the entire measurement period, noise stayed over 80dB for an entire minute only twice in St Dunstans (July 11th, 5-6pm; and August 3rd, 1-2pm) and four times in St Stephens (July 10th, 5-6pm; July 25th, 9-10am and 5-6pm; and July 26th, 5-6pm). It never went above 85dB. However, the threshold was reached within every hour for at least 10s and up to 90s, which may be particularly relevant for children or others who may have greater vulnerability.

In sum, the results show that even though the average noise level in both locations does not exceed the official threshold, it constitutes a serious annoyance with recurring peaks of harmful levels occurring every day. It is hence likely that these noise levels result in harmful psychological and health effects in the long run.

3.3 Engine idling behaviour

Having described the overall context, we now present the results of the experiment on engine idling behaviour. We initially analysed data for the two locations separately. However, because the results showed that the baseline prevalence of engine idling was similar at both locations, and for clarity of presentation, we provide results for the two locations combined. Results for each location separately are reported in Appendix 5.

During the testing periods, 6,528 vehicles were observed. Overall, 68% of drivers left their engine running while waiting at the level crossing. The prevalence of engine idling differed greatly amongst different types of vehicles (see Table 6). While 75% of bus engines stopped idling[4], around 80% of lorry, van, and service vehicles continued to idle.

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[4] A majority of buses in Canterbury are run by Stagecoach group, which monitors their drivers' engine idling.

CONTINUED OVERLEAF

THE PRESENT INTERVENTION (CONT)

Given these differences between vehicle types, and because some categories of vehicle did not appear frequently enough to provide sufficient numbers of valid observations, we focused the analyses on the 5,331 cars that were observed. The effect of the intervention messages for all vehicles is reported in Appendix 6.

Results are summarised in Table 7 and illustrated in Figure 9. We found that the three intervention messages significantly reduced car engine idling. Compared to 74% at baseline measurement, the proportion of idling engines when the messages were present was between 60-69%. There are different ways to depict this effect. For example, given that 26.4% complied with the need to switch engines off in the baseline, we can state that the messages increased compliance by between 16% and 38%. Statistical tests confirmed that these effects were strong enough to be reliably attributed to the messages themselves, and not to random variations. We conducted further tests to establish whether idling levels were attributable to other factors that could have influenced the drivers' behaviour, such as number of persons in the car, presence of children in the car, car windows being open, and outside temperature. However, these factors did not change the effects of the persuasive messages.

Finally, comparisons between the three intervention messages revealed that the Responsibility message, "Join other responsible drivers in Canterbury. Turn off your engine when the barriers are down", was the most effective.

Table 7: Percentage of observed engine idling behaviour as a function of the intervention message, amongst car drivers.

	Cars idling	Cars with engine off	Number of cars
Baseline	73.6%	26.4%	1,355
Responsibility	59.5%	40.5%	1,212
Effectiveness	65.9%	34.1%	1,397
Reflect	69.4%	30.6%	1,367

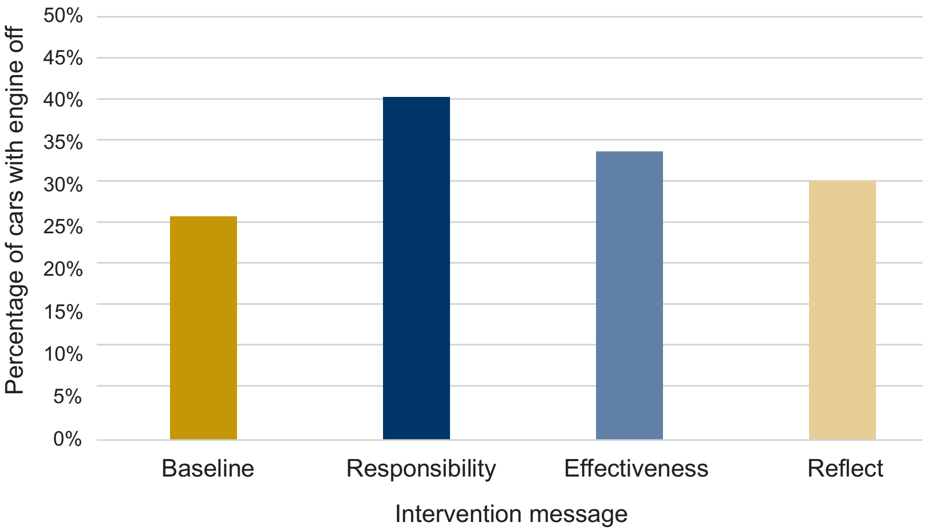

Figure 9: Percentage of cars with their engine off as a function of the intervention message.

CONCLUSIONS

1 Air pollution and noise levels

In this report, we summarised the results of an experimental intervention aiming to tackle the air pollution problem in Canterbury. We presented data obtained from two level crossings in the 2018 summer in terms of engine idling, air pollution (three indicators), and noise levels. We assessed the effectiveness of different intervention messages posted near the level crossings on drivers' engine idling behaviour.

The pollution monitoring data showed that air quality and noise levels were both problematic. It is worth noting that air quality and noise levels were similarly hazardous in both locations despite the fact that only St Dunstans is in the AQMA. Although average levels of air pollution tended to stay below the threshold, we found a high probability that people in these two areas would be exposed to above-threshold levels of pollutants during daytime hours. Pollutant concentrations are higher nearer to ground level and dilute with height (Embaby, Mayhoub, Essa, & Etman, 2002). Pollution levels near the ground are therefore likely to be higher than those measured by our monitors, which were 2.5 metres above the ground. The risk of dangerous levels of exposure is therefore most serious for babies in pushchairs, young pedestrians, and those in wheelchairs or mobility scooters whose head heights are lower and whose lungs are particularly vulnerable (Sharma & Kumar, 2018).

We found that noise levels exceeded 80dB only for brief periods (mostly up to a minute) during the measurement hours. Average noise levels in both locations were below 70dB. However, the proportion of one-hour time intervals in which noise levels exceeded 70dB was relatively high in both locations. Hence, chronic exposure to these noise levels might have a considerable impact on pedestrians and people who work near level crossings.

2 Engine idling

Most importantly, this project demonstrated the efficacy of using road signage to deliver messages that can successfully reduce engine idling. Specifically, three different intervention messages displayed near level crossings in two different locations increased the proportion of drivers who switched off their engines by up to 38%. Translated in concrete consequences for Canterbury, this impact on idling would prevent the emission of 536 tons of CO_2 per year. This is equivalent to saving 241,360 litres of fuel, or taking 123 cars off of the road for the entire year.[5]

It is also equivalent to planting 8,863 trees or switching 20,359 incandescent lightbulbs to LED.[6] This is very encouraging, especially when considering that the signs used were quite small (30% smaller than originally planned owing to unexpected restrictions by KCC), and that the messages were only displayed for a limited period. Our findings demonstrate promising avenues for tackling pollution.

First, we would anticipate that the introduction of permanent, larger, and more visible signs near level crossings and other long-wait stops (eg some traffic lights, schools) would have a further positive effect. It seems likely too that having such messages distributed across different locations and in a sustained manner is likely to yield even greater benefits as new norms become established. We would also suggest that a more dynamic form of signage (eg, electric signs that vary a series of different messages known to be effective) may be particularly effective.

A similar scientific approach to deployment of persuasive messages could be used to encourage other behaviours related to amelioration of air quality, such as the use of public transport, cycling, and so on. Enforcement methods (eg, implementing anti-idling fees) can often reinforce counterproductive behaviour because they are mostly based on external motivation (Deci & Ryan, 1980). Such motivation is often only effective in the short-term. Behaviour change that is achieved through persuasion and normative shifts is more likely to be sustained over the long-term. Therefore, for longer term impact, the types of persuasive messaging used in this project seem well suited to addressing problems such as engine idling.

In conclusion, we believe there are plenty of good avenues for capitalising on the success of this project, and that by working creatively with local agencies, substantial gains can be achieved in the future. Basing interventions on sound scientific theory and careful measurement, in combination with the use of imaginative and creative forms of delivery, seems likely to offer very promising ways to tackle these community-wide challenges.

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[5] Calculation based on an average number of 70'000 cars registered in Canterbury (Canterbury City Council, 2018) and on average gas emissions by car (https://www.nrcan.gc.ca/energy/efficiency/communities-infrastructure/transportation/cars-light-trucks/idling/4415).

[6] Calculation made from: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

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APPENDICES

Appendix 1

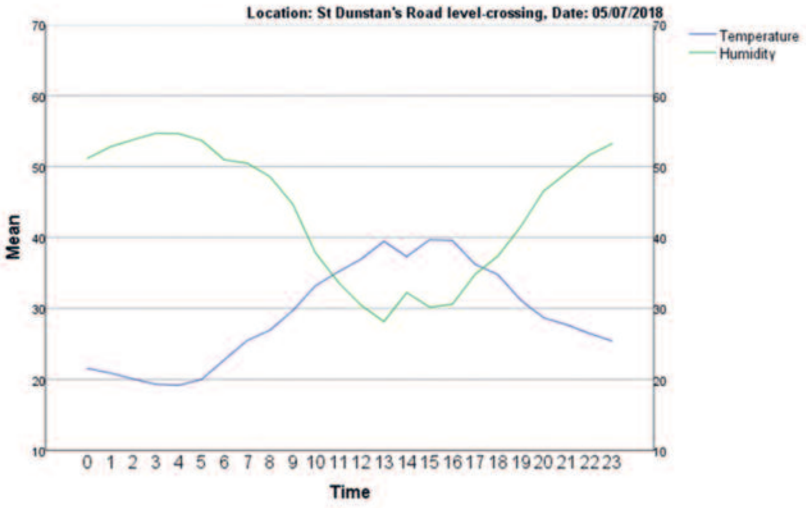
Correlations between temperature, humidity, and concentration level of NO_2, O_3, and $PM_{2.5}$. Coefficients are Pearson's r.

	St Dunstans			St Stephens		
	NO_2	O_3	$PM_{2.5}$	NO_2	O_3	$PM_{2.5}$
Temperature	+.23	+.79	+.58	+.06	+.82	+.21
Humidity	-.22	-.78	-.56	-.07	-.81	-.17

Note: Conventionally, coefficients < |.10| are considered small; coefficients < |.30| are medium; and coefficients > |.50| are large.

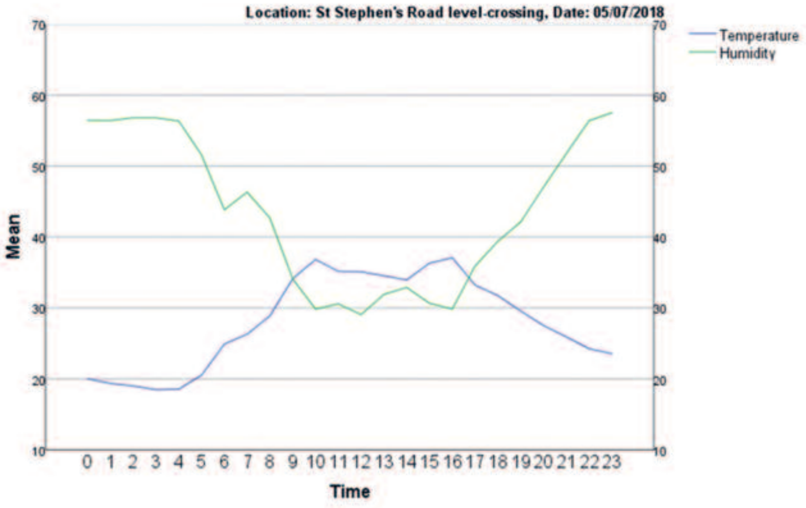
Appendix 2

Hourly averages for temperature and humidity levels for St Dunstans road for July 5th.



Appendix 3

Hourly averages for temperature and humidity levels for St Stephens road for July 5th.



CONTINUED OVERLEAF

APPENDICES (CONT)

Appendix 4

Number of seconds per hour interval when noise level exceeded 80 dB, presented by location and averaged by time interval across the five weeks.

	St Dunstans				St Stephens			
	9am	1pm	5pm	Grand mean	9am	1pm	5pm	Grand mean
Hourly average	32.4s	33.3s	31.9s	32.4s	37.7s	40.3s	45.1s	41.24s
SD	17.85	15.69	17.24	16.40	18.10	10.54	23.53	17.90

Appendix 5

Percentage of observed engine idling behaviour as a function of the intervention message, amongst car drivers, for St Dunstans and St Stephens separately.

	St Dunstans			St Stephens		
	Vehicles idling	Vehicles with engine off	Number of vehicles	Vehicles idling	Vehicles with engine off	Number of vehicles
Baseline	71.9%	28.1%	752	73.9%	26.1%	865
Responsibility	61.1%	38.9%	727	60.6%	39.4%	795
Effectiveness	65.6%	34.4%	860	66.2%	33.8%	856
Reflect	73.1%	26.9%	787	67.5%	32.5%	886

Appendix 6

Percentage of observed engine idling behaviour as a function of the intervention message, for all types of vehicles together.

	Vehicles idling	Vehicles with engine off	Number of vehicles
Baseline	73.0%	27.0%	1,617
Responsibility	60.8%	39.2%	1,522
Effectiveness	65.9%	34.1%	1,716
Reflect	70.1%	29.9%	1,673

School of Psychology, Keynes College, University of Kent, Canterbury, Kent CT2 7NP
T: +44 (0)1227 823961 E: psych-gen@kent.ac.uk www.kent.ac.uk/psychology

University of Kent

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