Preliminary study comparing dogs' responses to travel in electric cars

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Abstract: Many pet dogs (Canis lupus familiaris) will travel in a car at some point in their life, which can be stressful and lead to a range of potentially problematic responses. Electric vehicles are noticeably quieter than ones with internal combustion engines but there are no studies on their effect on dogs. Therefore, the aim of this study was to undertake a preliminary examination using a mixed methods approach to identify potential issues worthy of further investigation by comparing the dog's behavioural and physiological (heart rate) responses when travelling in these two types of car. 20 dogs undertook the same ~10 minute journey twice, once in each of the vehicles. As a pilot study, we focus primarily on reporting qualitative evaluations of results and effect sizes, with statistical significance references given where apparent. The behaviour of dogs seemed to be affected by the type of vehicle that they travelled in, with dogs appearing to be behaviourally more restless in the diesel vehicle than the electric one, indicated by shorter bouts of lying relaxed and alert. In a clinical assessment of individual dogs, we noted that two dogs appearing to suffer from nausea seemed to show potential improvements associated with travel in the electric vehicle.

Keywords: behaviour; diesel; nausea; problem behaviour; sickness; vehicle

HIGHLIGHTS

- 20 dogs undertook the same journey in an electric and a diesel vehicle
- Dogs travelling in the electric vehicle appeared to be behaviourally less restless than in the diesel one
- Two dogs appearing to suffer from nausea seemed to improve when travelling in the electric vehicle

INTRODUCTION

Many dogs will travel in a car at some time, and this may be stressful (Wöhr and Erhard 2004) or cause problems for the owner. It has been suggested that problematic behaviour may often arise because the dog is excitable, nauseous, tense, attention-seeking or needs to eliminate (Gandia Estellés and Mills 2006). One survey in the UK (Mills and Mills 2003) estimated that 23 per cent of dogs are restless when they travel, while in Italy, it is reported that over a quarter (Mariti et al. 2012) and possibly in excess of 40% of dogs have travel-related problems (Cannas et al. 2010). The prevalence of specific problems remains largely unknown, although around 15% of dogs are reported to suffer from motion sickness (Osgood 1978, cited by Mariti et al. 2012) and one study in Germany reports that 4.5% of dogs were fearful/anxious in the car (Tiefenbach 2001), cited by Mariti et al. 2012. Common signs include: a failure to respond to commands, restlessness, increased vigilance, vocalisation, running around, jumping up, seeking attention, attempts to get close to the owner/driver, trembling, panting, salivating, swallowing, yawning and potentially vomiting with increased startling, lip licking and vomiting, cowering and hiding and elimination being less common signs shown by less than half of dogs (Gandia Estellés and Mills 2006; Cannas et al. 2010). Problems can not only result from motion sickness arising from conflicting signals between the vestibular system and visual cortex (Money and Friedberg 1964; Conder et al. 2008), but also from a learned association with an aversive experience; for example Mariti and colleagues (2012) report dogs who only travel in the car to the veterinary clinic, were about twice as likely to develop problems in the car. Accordingly, if a trip has been aversive, dogs might subsequently find the car and journeys in it aversive, leading to a range of potentially problematic responses. Excitement and anxiety might also be expected from individuals with higher levels of "sensitive processing sensitivity" (Braem et al. 2017) as a result of the increased stimulation arising from travelling in a car. "Sensitive processing sensitivity" is an aspect of temperament originally described in the scientific literature relating to people (Aron and Aron 1997) and subsequently in dogs (Braem et al. 2017), that describes "an increased sensitivity of the central nervous system and a deeper cognitive processing of physical, social and emotional stimuli" (Boterberg and Warreyn 2016). This means individuals scoring high on this trait make greater use of stored memories for processing and so are more likely to be overstimulated by external stimuli. By contrast to cars with internal combustion engines (ICE), electric vehicles are noticeably quieter (Jabben et al. 2012). An unpublished research report by Fiat Professional about the effect of noise on human stress, reported lower levels of stress for drivers operating an electric van when compared with an ICE one of the same make and model (Stellantis 2021). The electric vans were measured to run 10dB quieter in the cabin than the ICE ones. The drivers, when responding to the 'perceived stress' questionnaire (Levenstein et al. 1993), reported feeling less stressed with these electric vans. Moreover, measurements showed lower heart rate, lower sweat levels, and lower body temperature when the drivers were operating the electric vans. Similar effects may happen with dog, but to the author's knowledge there are no studies yet on the effect of electric vehicles on dogs.

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Electric cars also bring the added benefit of reduced environmental impact from fossil fuels. The significance of this in relation to dog car travel should not be underestimated with Mackenzie and Cho (2020) calculating that, in Seattle alone, ~1.6 million vehicle miles and more than 700 tonnes of CO2-equivalent are generated from driving dogs to dog parks in that area. Likewise, Kent and Mulley (2017) identified a high level of car use for dog-related trips in Sydney, with an estimated 2.4 million dog-related car trips occurring in this city each week. Indeed Phillips et al. (2021) have identified a strong association between the rate of dog ownership and distance travelled by car per person even when controlling for income, level of urbanisation, housing type, and demographics. The popularity of electric cars is growing with several traditional major car manufacturers taking large strides towards the electrification of their vehicles. Indeed, General Motors has indicated that they will electrify all their cars by 2035; Ford aims to sell only electric cars in Europe from 2030; and Volkswagen has set a target of having electric cars making up 70% of new car sales by 2030 (Fayziyev et al. 2022). These cars inevitably create local magnetic fields (Ptitsyna and Ponzetto 2012), which increase when the car is moving, but these are generally considered safe to humans (Cotiu et al. 2020). Although, there are no reports of health or welfare problems in dogs associated with electromagnetism, dogs are known to be sensitive to magnetic force (Hart et al. 2013) and may change their behaviour in a local magnetic field (e.g. as a result of the introduction of a buried magnets (Yosef et al. 2020)). Given the trends in electric car ownership, the importance of car transport to dog owners and the potential effect of the environment created by the interior of a car, it is perhaps surprising that there appears to be no research on the effect of electric cars on dog behaviour and physiology.

Therefore, in line with established scientific principles (Jaeger and Halliday 1998) especially when generating scientific data that can have real world value in terms of affecting the behaviour of ordinary people (e.g. Kimmelman et al. 2014), the aim of this study was to conduct an initial exploration of this matter, using mixed methods alongside the calculation of effect sizes, with a view to gaining insight into the potentially most important effects for more rigorous quantitative study in future (Mills 2022). In order to describe what phenomenological differences in experience might occur in dogs when travelling in electric versus diesel cars we included a tentative quantitative comparison of the behavioural and physiological differences noted when travelling in these two types of vehicle, and supplemented this with qualitative clinical assessment of their individual reactions.

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METHODS

Animals

This research took place on the 20th and 27th October 2022 at the University of Lincoln (United Kingdom). Twenty privately-owned dogs of various breeds, aged 11 months to 14 years old (X ± SD = 6.4 years ± 3.5, N = 20) with 8 males and 12 females were recruited to take part (Supplementary Table S1). Inclusion criteria were that dogs were over six months old (and so had a degree of maturity in relation to car travelling) and at least medium size (more than 40 cm and above 16 kg – so that the heart rate monitor would stand a good chance of fitting). Aggressive dogs were excluded. Subjects with known problems during transport were not targeted in the recruitment phase, and no dog was considered a problem traveller. Only one out of the 20 dogs had already travelled in an electric car.

Experimental set-up

Four different cars (two pairs of equivalent vehicles) were used, to accommodate different sized dogs: two electric and two diesel from two different manufacturers. The Volkswagen cars were an ID.3 (Electric) and a T-Roc (Diesel). The two Genesis cars were the GV70 model one in electric and in diesel. Each dog undertook the same, approximately ten-minute, journey (with a two-minute stationary period at the start and end of the journey) twice: once in an electric vehicle and once in the diesel equivalent. The type of vehicle chosen first was counterbalanced across subjects (Supplementary Table S1).

Recordings

Behavioural

The behaviour of dogs in the cars was continuously recorded using a GoPro camera held by an experimenter. The behavioural response of dogs when travelling in different cars was evaluated using an ethogram (Table 1) adapted from Gandia Estelles and Mills (2006) and Mariti et al. (2012). This ethogram includes all the potential behaviours which can be observed when dogs are travelling in car. Duration and frequency of each behaviour were recorded, except for 'vomiting' and 'elimination' for which only the frequency was recorded; for the behaviours 'yawning', 'lip licking' and 'salivating' a 1-0 sampling method every minute was used.

Physiological

Heart rate was recorded using a Polar H10 heart rate monitor, strapped to the dog's chest. Conductive gel was applied to the position of the electrodes on the dog in order to improve the contact with the skin. Self-adhesive bandages were used to keep the belt in place (Bergeron et al. 2002; Affenzeller et al. 2017; Figure 1).

The mean heart rate was measured during the two minutes before and after completing the standard route in each of the two cars (electric and diesel engines). For the analysis, we used the difference in mean heart rate between these two 2-minute recordings i.e. the difference in mean heart rate after being subjected to the car trip. Useable heart rate data was obtained for 11 dogs

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Behaviour	Definition	Measurements	References
Barking	'Rough' sound of very short duration, often repeated in quick succession.	D + F	Tod et al. 2005; Protopopova et al. 2014
Whining	Sustained whimper.	D + F	Tod et al. 2005
Yawning	Mouth open wide and inhalation for a period of a few seconds, then closes.	1-0	Tod et al. 2005; Rehn and Keeling 2011
Panting	Mouth open with tongue exposed accompanied with audible and/or observable rapid breathing and expansion/ contraction of chest.	D + F	Tod et al. 2005; Protopopova et al. 2014
Lip licking	Tongue extends to touch lip, before retracting into mouth.	1-0	Tod et al. 2005
Licking surface	Tongue extends to touch surface before retracting into mouth.	D + F	Tod et al. 2005
Salivating	Saliva hanging from mouth.	1-0	Parthasarathy and Crowell-Davis 2006
Vomiting	Matter expelled from mouth open; may be preceded by repeated abdominal heaving.	F	Protopopova et al. 2014
Elimination	Urinate and/or defecate.	F	Parthasarathy and Crowell-Davis 2006
Trembling	All or part of body visibly shaking.	D + F	Tod et al. 2005; Parthasarathy and Crowell-Davis 2006
Cowering	Body is lowered, crouched position.	D + F	Protopopova et al. 2014
Sitting	Hind quarters on ground with front two legs being used for support.	D + F	Tod et al. 2005

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Behaviour	Definition	Measurements	References
Lying alert	Dog is lying down but without its head in contact with the floor.	D + F	Rehn and Keeling 2011
Lying resting	Dog is lying down with its head in contact with the floor. Eyes may be opened or closed.	D + F	Tod et al. 2005; Rehn and Keeling 2011
Moving around	Moves from one point in the car to another; includes pacing and circling.	D + F	Parthasarathy and Crowell-Davis 2006
Jumping up	Forelegs or all legs not in contact with the ground.	D + F	Parthasarathy and Crowell-Davis 2006
Standing up	All four paws on ground and legs upright and extended supporting body, the head can be up.	D + F	Tod et al. 2005
Scratching	Scrapes front claws against car's surface.	D + F	Parthasarathy and Crowell-Davis 2006

Table 1. Behavioural signs during transport (adapted from Gandia Estelles and Mills 2006; Mariti et al. 2012). D = Duration, F = Frequency, 1-0 = Present-Absent (Sampling 1-0 every minute).

(connection loss was experienced with some dogs, others could not be fitted with an effective heart rate belt, etc.).

The data was analysed with the Kubios HRV 3.5.0 software. The heart rate data was checked for artefacts. A 'very low threshold' artefact correction level was applied (Amaya et al. 2020). For 4 of the 11 dogs, the heartbeat corrections were above the 5% threshold recommended by Kubios (Tarvainen et al. 2018) and so analyses with and without these four dogs were compared.

Experimental procedure

The dog was brought to the designated car and lifted into the back. All dogs travelled behind a dog guard as per the UK Highway Code, "Rules about animals", Other animals", section 57 (The Highway Code 2022). Once the experimenter was in place on the back seat of the car and the camera had been turned on, the heart rate of the dog was measured for a two-minute period with the engine off. After this two-minute period, the driver followed a route taking approximately ten minutes (Figure 2) before coming back to the starting point.

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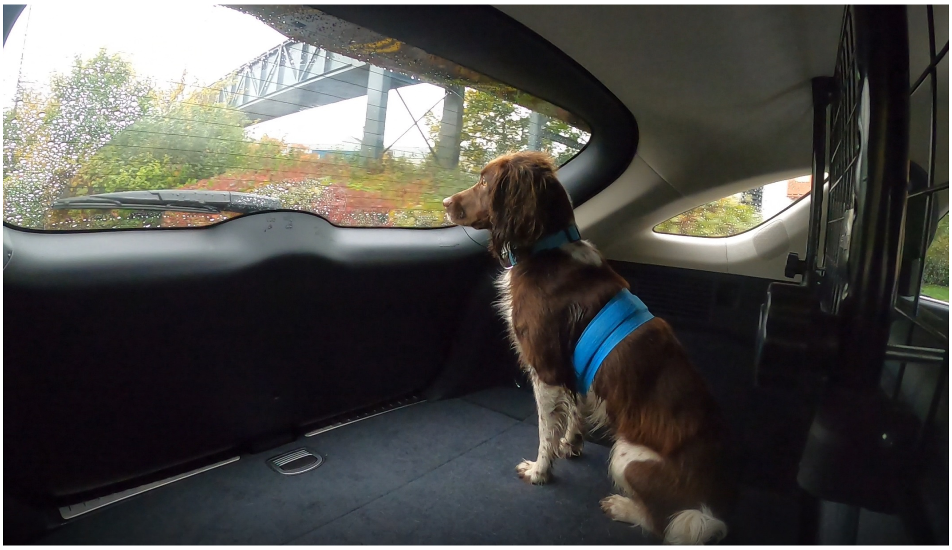

Figure 1. Heart rate belt strapped to a dog's chest.

Then, a second measurement of heart rate was performed for two minutes with the engine off. The dog's behaviour was tracked with the camera throughout. At the end of this second two-minute period the camera was turned off and the trial considered complete.

This procedure was the same for the electric and diesel car. The dogs had approximately one hour of rest between the two car trips and the same experimenter was present for the two trips of a given dog.

Data analysis

All analyses were performed with R software (version 3.5.2). Given the exploratory nature of the study, in line with the recommendations of Perneger (1998) no corrections were made for multiple testing. This is because, in the early stages of exploring the factors related to a phenomenon, the practical significance of a type II statistical error (false negative) was greater than a type I error (false positive). Given that our focus was on identifying points of potential clinical significance, we calculated effect sizes (Hedges' g) for measures of interest and examined the idiographic features of cases using qualitative methods (Mills 2022).

Assessment of potential confound related to trip duration

As the exact journey time could not be controlled, we first verified that there was no significant difference in average journey times between the two car types using a paired t test.

Analysis of effect of the different car type on the duration and frequency of behaviours during the trip.

Standardisation of metrics was achieved by converting the duration of behaviours into a percentage of the car trip and the frequency of behaviours

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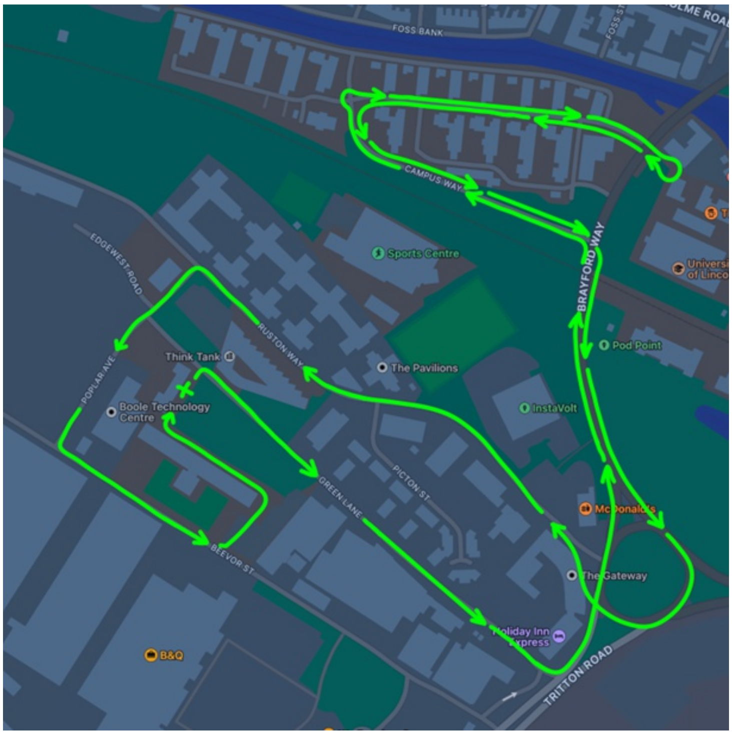

Figure 2. Map of the route taken by the cars during the experiment (Note: the cross corresponds to the start and end of the trip).

into a rate per second to allow comparison between the trials. Wilcoxon tests were used to establish any statistically significant differences in these measures, with Hedge's g calculated to examine effect size regardless of statistical significance. In order to control for a potential effect of car model, we also calculated Hedges g effect sizes for the 14 dogs who travelled only in the electric and diesel versions of the Genesis i.e. identical model with only a change of engine type.

Analysis of effect of car trip on the average values of the heart rate

In order to compare the difference in mean heart rate before versus after the journey, for the dogs who provided adequate data, a paired t test was used on those who provided the cleanest data, which met the threshold for artefacts (seven dogs) as well as all dogs for whom we had usable data (11 dogs), with Hedge's g used to assess the magnitude of differences seen. As above, in order to control for car model potential effect, we also calculated effect sizes for the 14 dogs who travelled only in the electric and diesel versions of the Genesis.

Qualitative and idiographic assessment of dogs during journeys

The behaviour of dogs during travel was rated from a clinical perspective to allow initial exploration of individual effects. The videos were reviewed by an experienced veterinary behaviourist and each dog's behaviour in the car evaluated for at least the precursors of one of the following problematic categories (Gandia Estellés and Mills 2006): excitable, nauseous, tense, attention-seeking and elimination or classified as being non-problematic. The

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data-sheet containing subjects' behaviour was then evaluated to determine whether the independently coded data was consistent with the profiles described for these problems (Gandia Estellés and Mills 2006), in order to ascertain preliminary evidence of convergent validity with the clinical assessment. The behaviour and physiological responses of cases were then examined post hoc for observations of potential associations to inductively generate hypotheses worthy of future investigation.

RESULTS

Assessment of potential confound related to trip duration

The average duration of the trip was 626 seconds (SD = 59.67) in the electric and 619.3 seconds (SD = 53.66) in the diesel car. These values are not significantly different (Paired t test: t_{19}= 0.42; P = 0.676).

Analysis of effect of the different car type on the duration and frequency of behaviours during the trip

'Sitting' was the most commonly expressed behaviour by dogs at 90% (Table 2). During the trials no dogs expressed: 'barking', 'vomiting', 'elimination', 'jumping' or 'scratching'. 'Cowering' and 'trembling' were expressed by only one specific dog, as was 'licking surface'.

There was no significant difference in the duration of any behaviours between electric and diesel cars (Table 3) and the related effect sizes were negligible to small (g=|0.02|-|0.31|). This also applied to dogs travelling in Genesis vehicles, (g=|0.02|-|0.29|).

Behaviours	N Electric	N Diesel	N total (%)
Whining	8	6	14 (35%)
Panting	13	14	27 (67.5%)
Sitting	17	19	36 (90%)
Lying alert	15	15	30 (75%)
Lying resting	7	10	17 (42.5%)
Moving around	11	14	25 (62.5%)
Standing up	10	11	21 (52.5%)
Salivating	4	5	9 (22.5%)
Lip licking	17	18	35 (87.5%)
Yawning	8	11	19 (47.5%)

Table 2. Number and proportion of dogs expressing specific behaviours in each vehicle type and overall. N = number of dogs which expressed this behaviour

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Behaviours	Electric Mean (SD)	Diesel Mean (SD)	W	*p-value*
Whining	2.92 (10.47)	3.37 (13.22)	27	0.625
Panting	38.18 (37.18)	36.74 (35.33)	57	0.802
Sitting	42.20 (36.89)	35.41 (34.03)	101	0.256
Lying alert	37.23 (37.59)	35.53 (33.89)	70	0.938
Lying resting	8.84 (23.15)	16.61 (25.31)	14	0.185
Moving around	1.85 (2.67)	2.90 (3.48)	26	0.057
Standing up	8.97 (21.40)	8.52 (19.67)	53	0.625

Table 3. Comparison of duration of behaviours in percentage between electric and diesel car for the 20 dogs. Wilcoxon test [W]

Behaviours	Electric Mean (SD)	Diesel Mean (SD)	W	*p-value*
Whining	0.004 (0.009)	0.003 (0.006)	38	0.689
Panting	0.018 (0.020)	0.021 (0.020)	29	0.149
Sitting	0.006 (0.006)	0.007 (0.006)	78.5	0.520
Lying alert	0.008 (0.009)	0.012 (0.011)	19	**0.012**
Lying resting	0.004 (0.008)	0.014 (0.024)	1	**0.008**
Moving around	0.004 (0.007)	0.006 (0.007)	32	0.118
Standing up	0.003 (0.005)	0.005 (0.007)	30.5	0.311
Salivating*	0.084 (0.209)	0.094 (0.217)	6	0.787
Lip licking*	0.564 (0.384)	0.619 (0.380)	43	0.348
Yawning*	0.083 (0.109)	0.110 (0.136)	26	0.327

Table 4. Comparison of frequency of behaviours standardised as rate per second (or rate per minute, indicated by *) of behaviours in electric and diesel car for the 20 dogs. Wilcoxon test [W]. Significant values are highlighted in bold

Dogs expressed the behaviours 'lying alert' and 'lying resting' significantly more often (g= |0.41| & |0.48| respectively) in the diesel car than the electric one (Table 4). When focusing on those travelling in the Genesis, the differences in these same two behaviours were small to medium (g=|0.37|and|0.51| respectively). Other differences in frequency were negligible to small and not statistically significant (g=|0.04|-|0.26|). These other differences were also negligible to small (g=|0.01|-|0.30|) when looking at the dogs travelling only in the Genesis.

Analysis of effect of car trip on the average values of the heart rate

For the seven dogs who provided the most robust data, the reduction in heart rate as a result of the journey was (mean(standard deviation)) 15.57 (22.16) in

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the electric car and 0.43 (14.85) in the diesel one. This was a medium sized difference (g=0.75) but not statistically significant (Paired t test: t6= 1.35; P = 0.224). When focusing on dogs only travelling in Genesis vehicles, this was a large difference (g=1.22).

When the data set was extended to all the dogs for whom we had sufficient heart rate data, there was still a medium sized effect (g=0.64) and no significant difference between electric (X ± SD = 15.45 ± 18.12, N = 11) and diesel (X ± SD = 4.27 ± 14.01, N = 11) cars (Paired t test: t10= 1.41; P = 0.188). For the dogs who only travelled in Genesis vehicles, there was a large sized effect (g=0.92).

Qualitative and idiographic assessment of dogs during journeys

Using the terminology of Gandia Estellés and Mills (2006), one dog showed potential signs of low levels "attention-seeking", being frequently oriented towards the filming researcher. Inspection of the datasheet showed that this dog also expressed the highest duration and frequency of whining. This was the only dog for whom we had data, that showed their average heart rate went up as a result of travelling in the electric car (albeit by only 2 bpm), but having it reduce when travelling in the diesel car (by 14bpm). For this individual the diesel journey was the first trip undertaken.

One dog showed potential signs of "excitability". Inspection of the datasheet showed that this was the only dog to lick surfaces, he also vocalised but did not pant. No heart rate data was available on this subject.

Two dogs were clinically assessed as looking potentially "nauseous" (i.e. they salivated, hid and/or cowered; Gandia Estellés and Mills 2006), although none vomited. Post hoc inspection of the data sheet showed that these dogs had the highest frequency of lip-licking, and one of them was the only dog to show signs of trembling and cowering; both showed relatively long durations of panting quite frequently. Division of the duration of panting by frequency, revealed these dogs had amongst the longest bouts of panting. These two dogs also showed the biggest shifts in heart rate pre- versus post- journey, with both increasing it when travelling in the diesel car, which was also their second trip, but showing a decrease after their first trip which was in the electric car for both. This reduction was quite large being around 25-30% of the baseline value.

Six dogs appeared "tense" during the journey, i.e. that the dogs were trembling, yawning, panting, startling and trying to get close to the experimenter (Gandia Estellés and Mills 2006). Post hoc, inspection of the datasheets revealed that these dogs tended to pant a lot but not vocalise, they also tended to lip lick and yawn more than other dogs. Heart rate data was available for three of these but no potential patterns were detected.

No dog showed signs of "elimination" and ten dogs were assessed as not showing signs indicative being a potentially problematic traveller. Heart rate data was available for five of the latter. Four showed a reduction and one no change in heart-rate as a result of travel whatever the type of vehicle. Overall heart rate differences were generally small compared to the dogs above, although two dogs showed a marked difference but on just one of their trips.

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DISCUSSION

Our results indicate some statistically significant behavioural differences for dogs travelling in electric versus diesel vehicles and suggest potential individual effects which deserve further investigation. We found no evidence that electric vehicles have a detrimental effect on dog welfare, and in general other observed effects on dogs appear negligible.

The significant increase in lying alert and lying resting without a significant change in the duration of these behaviour in a diesel car, suggest that dogs are not settling as much in the diesel as electric car. The reason for this is unclear, but it might be the result of differences in the vibration and/or noise experienced in these cars. Perhaps somewhat surprisingly, dogs, ordinarily, appeared to show a reduction in heart rate as a result of travel which is counter to recent research findings (Hunt et al., 2023). However, there were limits on the number of dogs we could include in this evaluation, so the difference may be a random effect or perhaps the result of careful driving on a smooth route. Given the small sample size for this metric, a lack of statistically significant difference between vehicles is not surprising, but we also note the medium effect size, and that this might be greater when travelling in electric cars than diesel ones. This would be consistent with the behavioural evidence concerning lying behaviour that suggests dogs may be more restless in the diesel cars and consequently have a slightly lower reduction in heart rate than in the electric one. Thus these observations are worthy of further investigation, given the extent to which dogs are transported in cars (Kent and Mulley 2017; Philips et al. 2021) and concerns about the impact of travel on welfare in other species (e.g. cats (Tateo et al. 2022), horses (Padalino 2015)). Consistent evidence of a benefit in favour of electric cars combined with their ecological benefits might be meaningful to many owners.

As we were interested in exploring the effects on dogs in general, we did not target subjects with known problems in our recruitment. Nonetheless, about half of the dogs showed potential signs that could be indicative of early-stage problems, which is consistent with reports in previous literature (Cannas et al. 2010). The effect of travelling in electric vehicles on these problems cannot be deduced with any great certainty from this study, but examination of subjects on a case-by-case basis is of value, when considering potential priorities for future research. Perhaps most striking of these observations is the difference observed among the two dogs who appeared to show signs of nausea; both showed marked reductions in heart rate after their first trip (reduction of 47 and 45 bpm), which was in the electric car, but increases after their second trip (increase of 22 and 4 bpm), which was in a diesel car. In humans, increased motion sickness is associated with an increased heart rate (Holmes and Griffin 2001). We cannot tease out an order effect from an effect of car type, but the drop in heart rate data following the first trip, is not consistent with the dogs being more distressed by this as might be expected if it was a normal car trip. These two cases raise the intriguing possibility that dogs with motion sickness might travel better in an electric vehicle. Travel sickness in dogs is an important problem (Elwood et al. 2010) as evidenced by the development of licensed medications for this issue (Benchaoui et al. 2007), and so our observation here

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deserves further investigation. The single dog who was showing potential signs of attention-seeking, increased heart following the second trip in an electric car, but showed the commonly seen reduction following her first trip in the diesel car. The reasons for this are unclear. In general our results highlight the potential value of further research in this area, especially in relation to dogs with potential travel-related issues.

CONCLUSIONS

The behaviour of dogs was affected by the type of vehicle (electric versus diesel) that they travelled in, with dogs appearing to be more restless in the diesel vehicle than the electric one, as indicated by shorter bouts lying relaxed and alert. Other behaviours and heart rate were not noticeably affected by the type of vehicle. Close inspection of our data at the level of the individual revealed cases to suggest that dogs suffering from nausea may improve in an electric vehicle. Effects on dogs with other problems are harder to assess, and further research is warranted for all the effects reported here.

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ETHICAL APPROVAL

The delegated authority of the University of Lincoln Research Ethics Committee approved this study (reference: UoL2022_10183). Informed consent was obtained from all dog owners involved in the study.

CONFLICTS OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization of methodology: CR, DM; data curation: CR, DM, AB, ED, KP, JP, HS, AS; formal analysis, CR, DM; writing—original draft preparation, CR and DM; writing—review and editing, all authors have reviewed and approved the text; funding acquisition, DM. All authors have read and agreed to the published version of the manuscript.

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