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SID 5 Research Project Final Report

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Project identification

1. Defra Project code: AW1402
2. Project title: Studies to assess the effect of pet training aids, specifically remote static pulse systems, on the welfare of domestic dogs
3. Contractor organisation(s): University of Lincoln
   University of Bristol
   Food and Environment Research Agency
4. Total Defra project costs (agreed fixed price): £ 469,000
5. Project: start date .... September 2007
   end date .... November 2010

6. It is Defra's intention to publish this form.
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Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

This project assessed the welfare of dogs trained with pet training aids, specifically remote static pulse collar systems (e-collars). Previous work has focused on a very limited number of devices in a very limited range of contexts and the evidence of the impact of such devices on dog's overall quality of life is inconclusive. Project AW1402 aimed to assess the physical characteristics of the e-collars and the physiological, behavioural and psychological consequences of their use in dog training in four objectives.[1]

1. Investigate the resistance in the neck skin of a range of dogs

2. Measure the physical output properties of the devices under investigation

3. Evaluate methods for recording behavioural/psychological measures of emotional state in the context of dog training.

4. Investigate the long term behavioural, physiological and psychological effects of using training devices in the domestic dog

A representative selection of e-collars was purchased to allow the assessment of electrical properties in laboratory tests and the evaluation of manuals (Objective 2). As the electrical output of the e-collars depended on the impedance presented by the dogs' necks, this was measured first on a sample of dogs of a number of breed and cross-breeds under dry and wet conditions (Objective 1). This was done under supervision of an animal welfare specialist and did not cause pain or distress as indicative from the dogs' behaviours.

The impedance of dogs can be modelled as a passive resistance with a value of about 10kΩ (10^{th} -90^{th} percentile range 4 – 150kΩ) for wet dogs and 600kΩ (22 – 950kΩ) for dry dogs. The momentary stimulus generated by the e-collars comprised a sequence of identical short voltage pulses. The continuous stimulus comprised a much longer sequence of the same voltage pulses. There were considerable differences between tested e-collar models in the voltages, the number of pulses in, and length of each stimulus, but little variation within individual models of e-collars. The peak voltage delivered by e-collars varied significantly with the resistance of the dog, from as much as 6000V at 500kΩ to 100V at 5kΩ. The highest voltages were generated for only a few millionths

[1] NB. A further study AW1402A focussed on the immediate welfare consequences for dogs undergoing training with e-collars compared with dogs referred for similar behaviours but trained with positive reinforcement.

of a second. To allow meaningful comparisons between e-collars (taking into account the differences in electrical characteristics), a stimulus strength ranking indicator (SSRI) was developed. This showed differences between the selected e-collars, as well as differences in the relationship between momentary and continuous stimuli.

Manuals were clear on operation, but gave varying levels of information on using the e-collar in training. Generally they did not adequately explain their full potential, for instance with respect to using the tone or vibrate functions. Advice in manuals was not always taken up by end-users as evident from responses in owner questionnaire collected as part of objectives 3 and 4.

A pilot study involving 10 dogs with prior experience of e-collars and 10 control dogs (matched by age, sex, breed and where possible behavioural problem) was conducted to develop and evaluate protocols for assessing dog welfare in home and training environments (Objective 3). This was followed by a larger field study (Objective 4) involving 65 dogs with prior experience of e-collar training and 65 matched controls. Cases and matched controls for Objective 4 were initially recruited from a separate training methods survey distributed to dog owners to reduce sampling bias, but this was later supplemented by other recruitment methods.

Data collection in Objective 4 included:-
1. An owner questionnaire to collect demographic data on dogs and owners; and owner-reports of behaviour during training and efficacy of training methods.
2. First passage urine to measure cortisol, creatinine, and metabolites of the neuro-transmitters serotonin (5-HIAA) and dopamine (HVA).
3. Saliva for assay of cortisol prior to and during training.
4. Observations of dog behaviour during fitting of inactivated e-collar
5. Observation of dog behaviours during a series of standard training tasks ("stay", "leave" and "recall" and the situation for which the focal device was used) given by both owner and a researcher and conducted in the context where the focal device had been originally used for training. Each set of tests were repeated both without (Test 1) and with (Test 2) the wearing of a dummy or inactivated e-collar to enable comparisons to be made between measures for the same dogs when wearing an e-collar (which may predict the application of stimulus for the dog) and not.
6. A spatial discrimination task designed to use judgement bias to assess underlying affective state.

Questionnaire data included type of device used, time since use, owner perceptions of the success of training, and owner reports of behavioural responses to use. Training methods used by owners in the control group could be sub-divided into those mainly using positive reinforcement (reward based) training, and those using methods based largely on punishment or negative reinforcement. Most owners (68%) purchased e-collars new, mainly from the internet, though some owners borrowed or purchased second hand collars. Problems with recall (40%) and livestock worrying (33%) accounted for the majority of reasons for e-collars use, although some manuals included information on use for basic obedience. Owner reports on operation of devices suggested they were often unclear as to how best use e-collars in training and some appeared not to have followed manual advice (if available). 36% of owners reported vocalisations on first use, and 26% on subsequent use of e-collars. This suggested that operating levels may not have been set in accordance with manufacturer's instruction (where available), though due to owners often being unable to recall how they used the device this could not always be verified. Owners reported the addressed behaviours to be more severe in e-collar trained dogs than the controls. Owners showed a high degree of satisfaction with the effectiveness of all the training approaches used, though owners from the e-collar group were more likely to state they would prefer to try other forms of training in the future.

No significant differences between groups were identified for behaviours shown during collar fitting, although a wide range of behavioural responses among dogs were noted. These differences were considered likely to reflect response to novelty in the control group, and the specific events that usually followed collar fitting in the e-collar group such no consequence, going for a walk or stimulus application. Because of high variability between dogs, it was considered that differences in measures between the first series of training tasks (Test 1; conducted with no collar) and the second series of training tasks (Test 2; conducted with dogs wearing a dummy collar) would be more reliable than absolute differences between groups. There was a significant increase in salivary cortisol between tests in the e-collar group compared to the sub-group of dogs trained using positive reinforcement. A behavioural scale incorporating proportion of training period tense, an inverse of proportion of training time relaxed, and proportion of time with attention directed at owner (whoever was training) significantly increased in the e-collar group, as compared to both the whole control group and the sub-set of dogs predominantly trained using positive reinforcement. These differences may reflect increased emotional arousal in e-collar dogs as a result of previous learned associations with the collar. Data was collected for a further 11 control dogs who experienced both sets of standard training tasks but wearing no collar to test for potential order effects. Their behavioural and physiological responses were consistent with control dogs who wore the e-collar for the second set of tasks.

There was some evidence of higher baseline cortisol in control dogs compared with e-collar dogs in both the urinary cortisol: creatinine (reflecting cortisol production overnight before researcher arrival) and baseline salivary cortisol (taken after the arrival of the researcher and likely to be influenced by the events associated with visitor arrival and greeting) particularly when considering just the positive reinforcement sub-group. However these differences were small and found not to be significant when a multiple comparison Bonferroni correction was applied. There were no significant differences in neurotransmitter metabolites between the two groups. Neither were there significant differences between control and e-collar dogs with respect to speed to ambiguous probes in the judgement bias task. However, in the latter case, group effects were confounded by strong effects of arena size where different test spaces had been used.

Overall, this project has highlighted the very variable outcomes between individual dogs when trained using e-collars. The combination of differences in individual dog's perception of stimuli, different stimulus strength and characteristics from collars of different brands, differences between momentary and continuous stimuli, differences between training advice in manuals, differences in owner understanding of training approaches and how owners use the devices in a range of different circumstances are likely to lead to a wide range of training experiences for pet dogs. This variability in experience is evidenced in the data from trained dogs such as owner reports of their dogs' response to e-collar use.

Significant differences were, however, found in data collected from e-collar and control dogs undergoing standard training tests with and without dummy e-collars. These included a difference in the change in salivary cortisol between tests with e-collar dogs showing an increase and positive reinforcement dogs showing a lowering of salivary cortisol between the tests. There were also behavioural changes that were consistent with changes in emotional state, with e-collar dogs showing an increase in a behavioural scale incorporating time spent tense and the inverse of time relaxed between the two situations. These training tasks were designed as far as possible to replicate the context where e-collar training had occurred in the past, and indicate a shift towards higher levels of physiological and behavioural arousal in the e-collar dogs as well as a tendency to focus more on the owner than when they had not been wearing a collar.

Thus it seems reasonable to conclude that the previous use of e-collars in training is associated with behavioural and physiological responses that are consistent with negative emotional states. It is therefore suggested that the use of e-collars in training pet dogs leads to a negative impact on welfare, at least in a proportion of animals trained using this technique.

Project Report to Defra

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   - details of methods used and the results obtained, including statistical analysis (if appropriate);
   - a discussion of the results and their reliability;
   - the main implications of the findings;
   - possible future work; and
   - any action resulting from the research (e.g. IP, Knowledge Transfer).

STUDIES TO ASSESS THE EFFECT OF PET TRAINING AIDS, SPECIFICALLY REMOTE STATIC PULSE SYSTEMS, ON THE WELFARE OF DOMESTIC DOGS

FINAL REPORT ON DEFRA PROJECT AW1402

PREPARED BY:

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This project aimed to assess the welfare of dogs trained with remote static pulse collar systems (called e-collars throughout: See Glossary). The research reported here was limited to commercially available electronic training collars which emit an electrical stimulus controlled via a remote hand-held device. Other types of electronic collars such as 'anti-bark' collars, or collars that use a spray were outside the remit of the study, as were e-collars that are part of pet containment systems. Whilst many dog owners and trainers consider these devices to be valuable training aids, their use is controversial and has been banned in several European countries. Critics of e-collars argue that they cause unnecessary pain; and that other methods, such as positive reinforcement training, are more welfare compatible. Those in favour of e-collars argue that, when applied correctly, they can successfully modify undesirable behaviour, especially behaviour that is highly motivated and difficult to control using other methods. Existing evidence on the impact of such devices on dog's overall quality of life is inconclusive, particularly on the effects of their use in the pet dog population. This project therefore aimed to assess the physical characteristics of the devices and the physiological and behavioural consequences of their use in owned domestic dogs. A further study AW1402A focussed on the immediate welfare consequences for dogs undergoing training with e-collars compared with dogs referred for similar behaviours but trained with positive reinforcement.

Objectives of Project

1. Investigate the resistance in the neck skin of a range of dogs

2. Measure the physical output properties of the devices under investigation

3. Evaluate methods for recording behavioural/psychological measures of emotional state in the context of dog training.

4. Investigate the long term behavioural, physiological and psychological effects of using training devices on the domestic dog

Objective 1 - Introduction

The perception of an electric pulse or stimulus from a training collar by a dog will depend on three factors:

a. Physical properties of the electric stimulus emitted by the device,
b. Physical factors associated with the dog, such as the electrical impedance in the skin and related tissues,
c. Psychological factors associated with the dog, linking perception of the stimulus and the dogs' behavioural and physiological responses to its environment.

The physical strength of an electrical stimulus, and thus the intensity with which it may be perceived, is determined by the voltage and current generated by the device and by the electrical properties of the material (the impedance). The three are related via Ohm's law. With a high resistive impedance (e.g. 1MΩ), an e-collar could generate peak voltages in excess of 6kV, while with a lower impedance (e.g. 500Ω) the same e-collar would generate a peak voltage of only 20V. There is little published material on the impedance of dog skin. Klein (2000, 2006) estimates resistances of dry dog skin to be 80kΩ based on tests on a preparation of dry pig skin, which on wet skin decreases to 20-40kΩ.

Ethical considerations

Resistance was measured through application of a very short electric pulse, as described in the next section. The method was approved by all institutional ethical review processes, and discussed in detail with Fera's Home Office Inspector. Since this study was not expected to cause any, but if so no more than momentary harm, pain or distress the Home Office was satisfied that it did not require a Project Licence under the Animal (Scientific Procedures) Act 1986. However, if pilot study data at any point found that more than momentary pain, suffering, distress or lasting harm was being caused then the issue of a whether a licence would be required or not would be re-visited. A pilot session of six measurements on two dogs was carried out under supervision of a Named Veterinarian. Behaviours that could indicate fear, pain or distress were assessed. These included, but were not limited to, stopping play, reluctance to resume play directly after the stimulus was applied, attention re-direction, head, eye or ear movements. More overt behaviours indicating severe pain, fear or distress such as vocalisation and withdrawal were not expected, and did not occur. No behaviours indicating pain, fear or distress were seen during six applications of the single-pulse stimuli in either dog during these pilot sessions. This suggested that the single-pulse stimulus was either not perceived, or if perceived, was neither painful nor aversive. As expected the measurements and associated protocol did not require a Home Office Project Licence to proceed. During subsequent measurement sessions an assessment was made after every single-pulse stimulus as to whether, based on the dog's behaviour, sessions should be stopped or continued.

Methods

Impedance measurements were made under conditions very similar to those of a typical e-collar. This was achieved by basing the measurement system on a commercially available e-collar. This e-collar (E1a) emitted a stimulus comprising a rapid sequence of eight identical voltage pulses each with a maximum voltage of 4800V and duration of about 300µS, spaced 16mS apart. To reduce the intensity of the stimulus during the impedance measurements an electronic switch unit was attached to the receiver to permit only one of the eight pulses to pass. This reduced the total duration of the stimulus and thus greatly reduced its perceived intensity (Notermans, 1966). Pilot tests on a human researcher showed no evidence of a decrease in resistance over eight pulses, indicating that measuring resistance to a single pulse would yield the same, and thus valid, information as that obtained by applying a 'real life' eight pulse stimulus.

The measurement collar was further modified by separating the neck contacts from the electronic circuit and connecting them by a 2m long electrical cable, allowing voltage and current to be measured, whilst allowing the dogs to play and interact. The current was measured by passing it through a 100Ω resistor and measuring the voltage drop across this resistor. Simultaneous digital recordings of the voltage and the current delivered by the measurement collar were made using a digital oscilloscope. These recordings were later analysed by computer. The measurement collar was used with short or long contact points as appropriate for the type of coat.

35 dogs were recruited from private individuals who volunteered their dog(s) to take part. Where possible, six single-pulse stimuli were applied to each dog: three times when the coat was dry and three times when it was wet but not dripping. To provide distraction from the stimulus in case it was perceptible (a method successfully used in humans, e.g. Notermans, 1966 and Kleiber et al, 1999), dogs were enticed to interact with a toy and/or their owner or researcher whilst the single-pulse stimuli were applied. Sixty-four useable measurements were made on 27 dry dogs and 53 useable measurements were made on 22 wet dogs. Sex, status (neutered, spayed or entire), age, hair length, neck circumference, body condition (Purina http://www.purina.com/dog/weight-and-exercise/bodycondition.aspx - last accessed 11-11-11) and shoulder height were also noted for each dog.

Measurements were only taken from dogs that fell within the inclusion criteria which required that the dogs should be over six months old, motivated to play or interact, not of a nervous, fearful or aggressive disposition, not previously trained with electronic training aids and with a known background (i.e. not rescue dogs unless the full history was known). Before measurements commenced all owners were required to sign a consent form confirming this. Impedance was assessed on a range of breeds and cross-breeds representing a range of dog sizes and coat lengths, with gun-dogs (n=15) and terriers (n=7) most commonly represented.

Results

In the majority of cases dogs did not react when the single-pulse stimulus was applied. Where they did react, their responses were limited to ear or eye movement, momentary attention re-direction and in one case licking of lips and reluctance to re-engage in play. Whilst these behaviours may have been a reaction to the single-pulse stimulus, the stimulus was also always preceded by a tone and some dogs showed similar reactions (except lip licking) to the tone alone (which automatically sounded when the device was switched on). In the dog which exhibited lip licking, the sessions were discontinued; in all other instances sessions were continued by agreement of all present. Fewer measurements were taken from wet dogs than dry dogs because the dry measurements were made first and some dogs lost interest in play or interaction during the test sessions. This was taken as a sign of disinterest rather than pain, fear or distress to the single-pulse stimulus, as it did not occur immediately after the single-pulse stimulus was applied.

	10^{th} percentile	median	90^{th} percentile
Dry dogs	22kΩ	640kΩ	950kΩ
Wet dogs	4kΩ	10kΩ	150kΩ

Table 1. *Resistance values for wet and dry dogs.*

The results indicate that the impedance of the dogs could be described as a simple resistive load without a capacitive component. Resistance values were highly skewed, so median values and percentiles are presented in preference to mean values (Table 1). Variation in the resistance detected between replicate measurements was considerable in some cases. This was probably due to changes in the contact area and hairs between the contact points and the skin.

Discussion

The higher resistance presented by dry dogs is probably due to the properties of dog hair and the air gaps between the hairs, the layer of grease covering the skin and high resistance of the dry epidermal skin layers. The lower resistance of the wet dog is consistent with Klein (2006) and Lindsay (2005) as well as human data (IEC 2005). This is likely to be due to improved electrical conduction through wet hair using water pathways and larger area of contact with the skin due to conduction of the electricity through the moisture on the skin surface.

The large variation between successive measurements made it difficult to say whether the resistance of individual dogs differed significantly, since relatively few measurements were made on each dog in each condition (dry and wet). No obvious trends between the measured resistances and any of the measured factors, such as hair length and neck circumference were identified.

Objective 2. Examination of a selection of collars: electronic properties, user characteristics and instructions.

An internet search carried out in 2007 showed there to be over 170 different models of e-collars available for purchase by the UK consumer, marketed under at least 14 different brand names. The actual range of devices is probably smaller since some e-collars are sold with a number of different transmitter units, for example allowing more than one collar to be controlled independently from a single handset. In sales material, e-collars are generally described in terms of the 'target' dog (in terms of their size and sometimes demeanour), the number of levels, the range over which the device will work, and additional features, such as the ruggedness, water-proofing or flexibility in being able to control more than one dog. Some cite output as high, medium or low. The market for electronic training aids is undergoing continual development and not all models included in the testing are still for sale at the time of writing.

E-collars have a varying combination of two to four functions which can be controlled from the radio control handset. These are (a) a tone signal (b) a vibration signal, (c) a short electrical stimulus lasting between 4 and 500mS, referred to here as a 'momentary' stimulus, and (d) a 'continuous' stimulus, which lasts for as long as the appropriate button on the controller is pressed. This is usually time-limited. Selected e-collars were assessed on their electronic properties, their user characteristics and on the instructions supplied with the collar. A number of brands are members of the Electronic Collars Manufacturers Association (ECMA) which sets publically available electronic, safety and animal welfare standards for their members' products.

Collar selection

Thirteen e-collars were examined, representing nine e-collar brands ('brand' denoting a company and/or manufacturer) (Table 2). All models, except one, ('model' meaning a specific design of e-collar within a brand) chosen to represent a brand were selected based on information from end-users (obtained for objective 3 and 4). Participants reported using at least 35 different models from a total of nine different e-collar brands. All brands reported are represented in our selection. Models reported to be in use included the two best-selling models manufactured by ECMA members (based on information obtained from ECMA as advised in 2007). The selection of e-collars consisted of nine models that were purchased as new between 2007 and 2010; one that was given to Defra around 2005/2006, and three used e-collar models (of two brands) that were loaned by end-users.

ID	**Condition**	**Stimulus levels available**	**Number of collars tested**	Number of voltage pulses in momentary stimulus	Duration of momentary stimulus (mS)	Voltage pulses per second in continuous stimulus	Maximum duration of continuous stimulus (S)
N1	New	16	2	2	12	285	8
N2a	New	continuous[1]	2	272	420	514	10
N2b	Used	4	1	131	131	475	10
N3	New	15	1	15	80	90	11
N4	New	10	1	6	16	21/110	8.5
N5	New	1	2	n/a	n/a	10	>60[2]
E1a	New	8	1	8	120	n/a	n/a
E1b	New	8	2	n/a	n/a	17	7
E2	New	9	2	120	120	1000	11
E3a	New	127	2	3 or 6	10 or 20	80/119/255	12
E3b	Used	127	1	4	18	70/88/133	13
E4a	New	8	2	2	4	73	7
E4b	Used	8	2	2	4	57	7

Table 2. *E-collars tested, describing their condition, number of stimulus levels available, number of collars tested, and their basic characteristics. E-collars are identified as 'E' or 'N' for ECMA/non-ECMA members respectively. Where more than one duration or number of pulses is given the value increases as the strength of the stimulus is increased on the handset. [1]Intensity was adjusted using a continuous knob which, the instructions inform us, delivers in reality one of 64 discrete levels. [2]Tested for 60 seconds, it is presumed there is no cut-out.*

Where obtained new, the e-collars were bought anonymously, in most cases in duplicate and from different suppliers. All new collars except one were bought via the internet. One of the e-collar brands purchased was found to be an unauthorised counterfeit (N5). Use of this brand of e-collar was reported by one end-user but the collars are not available from the manufacturer. This counterfeit e-collar was included in the assessment as it is obtainable in the UK and was possibly attractive due to its low price. Each collar brand was assigned an identity code (Table 2). Where more than one model of a brand was examined, they are identified as a and b. E-collar E1a was an e-collar given to Defra and is no longer available for purchase. Collar N4 was bought from the United States.

Assessment of e-collar characteristics, electrical outputs and instructions
The voltage time histories generated by training collars were measured while they were loaded with resistances of 500kΩ, 50kΩ, 5kΩ and 0.5kΩ. The upper three of these resistances were selected to represent the range of resistances likely to be found when the collars are in use (Table 1). The lowest resistance (0.5kΩ) was included because it is the resistance used for output current measurement tests by ECMA members (ECMA, 2010). Measurements were made with the collars adjusted to give maximum stimulus, minimum stimulus and the value closest to the middle of the range. The repeatability of each collar was also estimated by making 12 measurements on each collar while it was set at the mid-range stimulus value and loaded with a 50kΩ resistance.

E-collars were assessed for functions and ease of use. Instruction manuals were assessed on whether they advised against the use on young and infirm animals; gave advice on avoiding pressure necrosis and information on proper use (ECMA, 2010). In addition the method recommended for selecting the starting stimulus level for each dog, and the recommended training strategy was noted. This assessment of training manuals was restricted to new collars only where a manual was available.

Results - Electrical characteristics and outputs
Table 2 also summarises the stimulus characteristics of the selected collars. This shows there are considerable differences in the stimulus properties between models. N5 is noticeable for being the only one without a 'cut-out' function. The off-period following the maximum duration of the continuous stimulation on other collars varied from the time taken to release and re-depress the button, to a 10-second shutdown before the stimulus could be re-applied. The momentary stimulus comprised a sequence of identical short voltage pulses. The continuous stimulus comprised a much longer sequence of the same voltage pulses. Figure 1 illustrates a single voltage pulse recorded from E3b set at maximum stimulus strength and loaded with a resistance of 500, 50, 5 and 0.5kΩ. A momentary stimulus with this e-collar comprised four of these pulses at 4mS intervals. This pattern is generally representative of the e-collars tested.

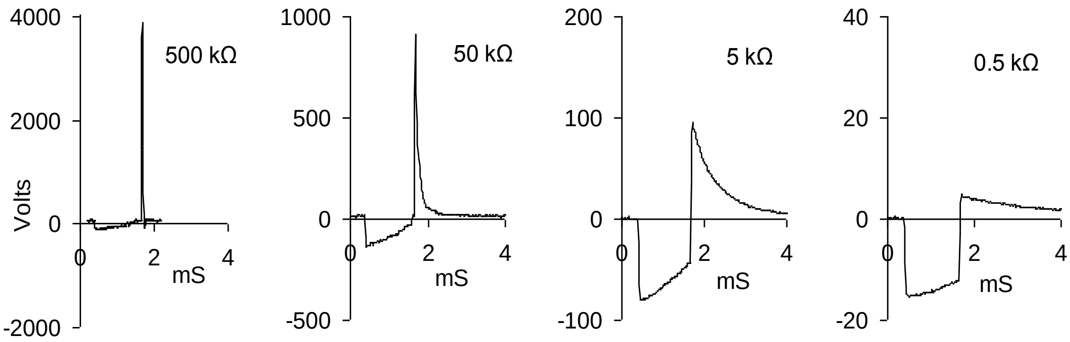


Figure 1 *Plots of a single voltage pulse from collar E3b set to maximum stimulus strength and loaded with a resistance of 500, 50, 5 and 0.5kΩ. A 'momentary' stimulus from this collar comprised four identical voltage pulses spaces at 4mS intervals.*

Table 3 shows the maximum voltages recorded for each e-collar model tested. Where two e-collars of the same type were tested the average of the two maxima is given. These results show that the maximum voltage is dependent on the resistance presented by the dog and that there are considerable differences between e-collar models. Although the maximum voltages can be very high, they are generated for only very short durations (as evident from Figure 1).The highest voltages last typically for only a few millionths of a second per voltage pulse.

Load	**N1**	**N2a**	**N2b**	**N3**	**N4**	**N5**	**E1a**	**E1b**	**E2**	**E3a**	**E3b**	**E4a**	**E4b**
500kΩ	4116	3569	2856	2491	5490	7350	4754	4864	950	5757	3888	4990	4527
50kΩ	1450	2210	2330	2150	1730	4026	692	786	430	1300	910	966	990
5kΩ	154	379	480	700	169	732	129	105	99	186	95	104	104
0.5kΩ	24	45	37	93	20	80	17	15	12	20	15	13	13
T_{50}	15	13	14	12	32	3	10	10	39	23	24	20	24

Table 3. *Maximum voltages (V) recorded with collars set to maximum stimulus strength. The resistive load applied is given in kΩ. The bottom line of the table shows T_{50}, the duration in μS for which the voltage in one voltage pulse exceeds 50% of the maximum voltage. This duration was measured using the 500kΩ load and maximum stimulus level.*

The complex shape and very short duration of the pulses together with the variable number of voltage pulses contained in one ‘momentary’ stimulus means a simple voltage measurement would not be an adequate means of quantifying electrical stimulus. A calculation of electrical energy dissipated by the device, however integrates the voltage and current over the time of application. Literature from the industry clearly implies that this is considered a better measure of the stimulus strength than voltage (eg Anon 2007). The electrical energy dissipated in one momentary stimulus is given in Table 4. These results show a wide range of energy levels, and with the most energetic stimulus usually occurring at neither the highest nor the lowest impedance.

Load	N1	N2a	N2b	N3	N4	N5*	E1a	E1b*	E2	E3a	E3b	E4a	E4b
500kΩ	1.4	60	24	1.2	6.8	2.6	3.3	7.3	16	7.6	2.7	1.4	1.6
50kΩ	3.5	287	152	12	18	13	5.0	12.4	54	17	4.4	3.3	3.4
5kΩ	5.0	285	154	40	17	8	4.7	6.5	30	27	6.5	2.4	2.3
0.5kΩ	2.2	223	196	44	4.1	0.9	0.7	1.6	4.1	3.9	2.1	0.4	0.4
ratio	143	2	4	6	19	n/a	n/a	n/a	8	43	33	37	29

Table 4. *Electrical energy (mJ) delivered by a momentary stimulus from collars set to give maximum stimulus level. The row marked ‘ratio’ indicates the ratio of the energy per second delivered by a continuous stimulus to that delivered by a single momentary stimulation. The collars E1b* and N5* have no momentary stimulus function, so results are given for a 1 second continuous impulse.*

An indication of the significance of the differences in these energy levels can perhaps be obtained by the observation that the energy dissipated by the e-collars set to their most powerful level is overall 81 times greater than the energy dissipated with the e-collars set to their least powerful level (this is the median figure, the range is 8-1114). This figure differs between e-collars and resistance values. This factor contrasts with the difference in energy dissipated when the resistance is varied from 500kΩ (typical dry dog) and 5kΩ (typical wet dog) for which the median ratio was 2.8 (range 0.6-32.9). This suggests that the e-collar manufacturers have succeeded in creating collars with broadly similar energy outputs, regardless of whether the dog is wet or dry and regardless of the intra-dog variation.

All the collars except E1a were able to deliver the longer continuous stimulus. It is of interest to compare the strength of the momentary stimulus and that of a continuous stimulus since a trainer may use either. Table 4 also includes the ratios of the energy delivered per second by a continuous stimulus to that delivered in one momentary stimulus. This shows that for a given dog and stimulus strength setting a continuous stimulus will deliver in one second anything between 2 and 143 times the electrical energy of a momentary stimulus depending on the model of e-collar. This difference between different training collars seems to indicate that the continuous function should be used with more caution on some e-collars than on others.

Many of the collars were purchased in pairs, which allowed some investigation of individual variation of e-collar properties. The mean difference between both the maximum voltages and the energy output for replicated e-collars was less than 10%. To assess repeatability of the stimuli of each e-collar, at least 12 measurements were made of the energy dissipated into a 50kΩ load with the collar set to deliver a mid-level stimulus. This showed that for each e-collar repeated application of the stimulus generally resulted in similar outputs. The standard deviation of the energy dissipated was on average 2.5% of the mean energy (standard errors ranged between 0.00004 & 0.0177).

Assessment of e-collar design and instructions

Physically, the collar mounted receiver units were typically 5-7 cm long and 3-4 cm wide and deep. They were attached to a plastic or webbed collar with two metal contact points protruding through the collar band to make contact with the dog’s neck. The contact points were 30–50 mm apart, 10-15 mm long and 3-6.5mm in diameter with smooth rounded ends. Longer contact points were often supplied for dogs with a thicker coat. The size of remote control handsets varied (they were comparable in both size and size variation to modern mobile phones). They had a reported range of between 100m to 1mile (i.e. approximately 1.6km).

The selected models were capable of different combinations of functions (Table 5). Nine of the ten new e-collars were capable of emitting a ‘continuous’ stimulation function and eight e-collars had a ‘momentary’ stimulation function - seven had both. Seven models could produce a tone on the receiver, two models could produce a vibration and one could produce either. In all models the tone or vibration signal could be used without the electronic stimulus. In four models the tone was factory-set, or could be programmed, to immediately and automatically precede an electronic stimulus. Three models allowed the user to customise functions of buttons. Where buttons could be customised these were not labelled. Otherwise, buttons were labelled with their functions on all other handsets except one.

ID	Level selection	‘momentary’ stimulation	‘continuous’ stimulation	Tone function	Tone paired?	Vibration function	Vibration paired?
N1	Stepwise dial	yes	yes	no	-	yes	no
N2a	Continuous dial	yes	yes	yes	no	no	-
N3	Buttons linked to digital display	yes	yes	yes	optional	no	-
N4	Step-wise dial	yes	yes	yes	no	no	no
N5	n/a	no	yes	yes	no	yes	no
E1a	Buttons linked to audible signal	yes	no	yes	yes	no	-
E1b	Step-wise dial	no	yes	yes	yes	no	-
E2	Buttons linked to digital display	yes	yes	yes	no	no	-
E3a	Continuous dial linked to digital display	yes	yes	no	-	yes	no
E4a	Step-wise dial	yes	yes	yes	yes[1]	no	-

Table 5. *Functions of selected e-collars. [1]Paired on ‘continuous’ stimulation only.*

All new e-collars contained a manual on operation. All gave advice on setting the level of stimulation most suitable for the individual dog in training; many gave examples of what behaviours indicate the dog has noticed the stimulation, but only three included a statement indicating that if the dog vocalises this level is set too high. All manuals included a caution on the fit of the collar and avoiding irritation of the skin which may result in pressure necrosis. Statements referring to age and health of dogs were made for many, but not all models. Most manuals included a statement advising against the use of e-collars on aggressive dogs, or at least suggested seeking professional help. All manuals advised on praising dogs on expressing the desired behaviour. Some manuals included advice on phasing out the use of the e-collar.

Manuals gave varying levels of information on training, some supplied as audio-visual material, but training advice varied between brands from limited, general advice on timing of the stimulus, to step by step examples of training scenarios. All manuals described use of e-collar in basic obedience training, with five out of the nine manuals including a section on dealing with specific problem behaviours, such as recall. Some manuals included advice on assessing why the dog is engaging in certain problem behaviours and whether there are alternative solutions to use of e-collars. With regards to basic obedience training, most manuals advised on teaching a command before introducing the e-collar. Some however suggested using the e-collar before introducing a command. When using the e-collar to stop the dog performing undesirable behaviours some manuals advised never to use a command, others advised it in specific circumstances. All e-collars had the option to emit either a paired or unpaired tone function or vibration, however, their use and potential was not explained in all manuals.

Most training advice favoured application of continuous stimuli until the dog showed the desired response. There was little advice on when the momentary stimulus could be used. Depending on the motivation of the target behaviour, manuals advocated training at the perception threshold or above as necessary. For ‘serious anti-social habits’ such as sheep chasing, one manual advised to start at least in the middle of the intensity range.

Discussion – Electrical Outputs

The aim of Objective 2 was to characterise a sample of e-collars. From investigation of individual models, it was apparent that there were more differences between the collars than could be learned from the information on the websites. E-collars produce repeatable stimuli, with little difference from pulse to pulse and little difference between collars of the same model. However, different collar models exhibited considerable differences in the electrical energy output of the stimuli, as well as stimulus characteristics such as differences in the number, frequency and duration of pulses. This information is not available to end-users.

Peak voltages delivered by e-collars varied with the resistance of the model dog, from as much as 6000v (at 500kΩ) to 100 V (at 5kΩ). These very high voltages are achieved for only a few millionths of a second. Part of the high voltage will be absorbed by hair, fat and dead skin layers that are not enervated. The variation in voltage with changes in impedance ensures that the electrical energy dissipated remains relatively constant regardless of the dogs' impedance or whether it is wet or dry.

Tests specified by ECMA for their members stipulate that collars should be tested to identify the maximum energy they put out over impedance range from 0.5kΩ to 100kΩ. This seems a reasonable test range, although a range from 4kΩ to 1000kΩ could be more relevant to dogs' properties. The ECMA "fixed output current test" however is specified for 0.5kΩ. Since this impedance is an order of magnitude lower than that measured in dogs, our results suggest that testing at higher impedances may be more relevant.

The counterfeit e-collar was unique in our sample in having only one level, and no limitation on the duration for which a 'continuous' stimulation can be applied. The instructions associated with one of the other collars specified that this limit was set to eight seconds whereas tests showed it to be 11 seconds. A cut-out function seems important to avoid accidental over-stimulation. Although reliability was not assessed systematically, two faults were found in the new collars. Although only one of these resulted in stimulation at a higher level, this indicates that a test to search out faults under conditions that may be encountered in the field should be part of a welfare oriented e-collar quality assurance scheme.

E-collars provide local stimulation and their effects are thus different from those generated by touching an electric fence. The effect is localised in the neck, where current flows between the electrodes, the pathway determined by the impedance of the different tissues encountered (Klein, 2006). Electric fences also differ from e-collars in dissipated energy. Electric fences typically generate peak voltages of 20kV and are capable of dissipating between 500 and 5000mJ of energy per pulse. These pulses occur typically once per second resulting in a dissipated energy of up to 5000mJ per second. By way of comparison, Ben Yaakov (2006) reports that the M26 Taser delivers between 300 and 1500mJ per pulse with 20 pulses per second, resulting an energy delivery of up to 30,000mJ per second. The strongest e-collars in our study delivered 1161mJ in a second set to its highest level (measured at 50kΩ).

Discussion - E-collar design and instructions
All manuals included instructions on the operation of e-collars, and all advised on praising the dog on expressing the desired behaviour. Some manuals gave background information on assessing why a dog engages in a particular undesirable behaviour, and gave suggestions of alternative strategies to try first. Although all manuals suggested starting at the lowest level when setting the right intensity for the individual dog in training, there were considerable differences in the explanation as to how this should be achieved. Behavioural signs indicative of the appropriate level ranged from the expression of specific behaviours such as attention redirection, to 'outward signs of discomfort or confusion'. The latter is ambiguous, and may be interpreted by inexperienced users as also including behaviours which occur at a high level of stimulation. Three brands included a warning that vocalisation indicates that the level is too high.

Manuals generally did not explain when to use momentary or continuous stimuli, which seemed to be left to the preference of the user. Neither did most explain the use of tone and/or vibration. Many placed emphasis on the use of continuous stimulus as a form of negative reinforcement in training. The variable relationship between continuous and momentary stimuli between e-collars (Table 4) means that the differences in dogs' perception of these stimuli are likely to be more pronounced in some e-collars than others.

In conclusion, whilst overall e-collars were easy to use, our assessment of the differences in amount and type of information included in the manuals assessed here suggests that there may not be enough information in all manuals to enable inexperienced users to use all functions of the e-collars to their full potential. Reports from end-users (Section 4) showed that a substantial number of dogs vocalised on initial and subsequent exposure to the stimulus and that stimulus levels were not always selected according to the advice in the manuals assessed here. This suggests that the guidance laid out in manual is not always followed, which may be due to mis-understanding the advice, not reading it, or deliberately using a different approach. Potentially this can lead to welfare implications associated with the use of punishers used at inappropriate levels or poorly timed. Given the often wide stimulus range of the devices, it is thus likely that different dogs have very different experiences of training with e-collar stimulation, depending on how the devices were used.

Information allowing end-users to choose one e-collar in preference to another is generally limited and does not allow meaningful comparisons between e-collars. Rarely does it give an indication of output characteristics of the device. In line with our findings both Klein (2006) and Lindsay (2005) comment that providing such information would be useful. This would have to be meaningful; differences in stimulus properties between e-collars make it difficult to compare how their stimuli may be perceived, and comparing levels of energy alone does not take into account the effects of the different pulse trains on the dog or its perception of the stimuli. The next section covers further work investigating the ranking of stimuli.

Stimulus ranking - Background and Rationale

No attempt was made in this project to assess what levels of electrical stimuli might be perceptible or noxious to dogs. However a comparison of the *relative* strength of stimuli as perceived by humans (i.e. A stronger than B), may be give some guidance of potential effects on dogs if used with caution. Given their basic physiological similarities it seems likely that short stimuli will be ranked in a similar way by humans and dogs. Such a comparison could lead to an objective method for identifying the relative strengths of the stimuli generated by e-collars.

Under conditions of constant resistance, voltage and current are proportional to each other so dissipated energy E (in Joules) is calculated as

$$E = P\int V(t)^2/R \, dt \quad = P\int I(t)^2 * R \, dt \quad (1)$$

where P is the number of voltage pulse repetitions, V is the Voltage, I the current and R the resistance.

It seems to be assumed that stimulus strength is related to dissipated energy. However examination of the literature on human perception of electrical stimuli (e.g. Ekman et al 1964; Tursky and Watson 1965; Notermans 1966; Rollman and Harris 1987) suggests that the use of V^2 or I^2 is correct but that the factor P should be raised to the power of 0.6; that a linear integration of time is not correct; and that the resistance R has a complex relationship with perceived stimulus strength.

To assess whether these research findings might be relevant for the human perception of the strength of the stimuli produced by e-collars a short trial was conducted. The interpretation of these results and its relevance to dogs is based on the assumption that the strength of short electrical stimuli will be ranked (but not necessarily rated) in the same way by humans and by dogs. Members of the research team and participating colleagues gave informed consent for this study.

Methods

Firstly, electrical impedance of a human forearm was measured to be 35-50 kΩ. Then, four e-collars (N2a, E2, E3a and E4a) were selected from those used in Objective 2, to achieve a spread of stimulus types while ensuring that over this measured range of impedance the dissipated energy was relatively constant and the ranking of the energy dissipated did not vary greatly. Therefore even if the exact impedance presented during tests did vary a little, the consequent variation in the energy output should be small.

Two male and two female human volunteers were exposed to pairs of e-collar stimuli at varying levels and were required to identify which of the two stimuli was the strongest. Sixteen different stimuli were used and a total of 146 comparisons were made between them in a random presentation to control for order effects. The electrical stimuli ranged in peak voltage from 138V to 680V and the number of voltage pulses ranged from 2 to 136.

The results of the comparison trials were used to generate a ranking of the stimuli used. Since the rankings provided by the four subjects were very similar the individual comparison results were pooled to identify a single optimal ranking. This perceived strength ranking was then compared with the electrical properties of the devices derived from bench-testing using a 39kΩ resistive impedance which was representative of the resistive properties of the volunteers' arms.

Results - Direct stimulus comparisons

Differences could be felt between the stimuli caused by the various e-collars with some higher levels feeling sharp, rather like a pin prick and others blunt more like a short cramp, however regardless of these differences it remained relatively easy to judge which stimuli were stronger. Although the correlation between dissipated energy and subjective stimulus strength ranking was 0.72 (Pearson correlation) and significant at p=0.001 (Figure 2). The results indicate that for each device, the perceived stimulus strength increases with energy, but that there are large differences in this relationship between e-collars, particularly where collars emitted large number of pulses per stimulus. Comparison between stimuli of the same energy indicated that those comprising many voltage pulses were perceived as less strong than those with fewer pulses.

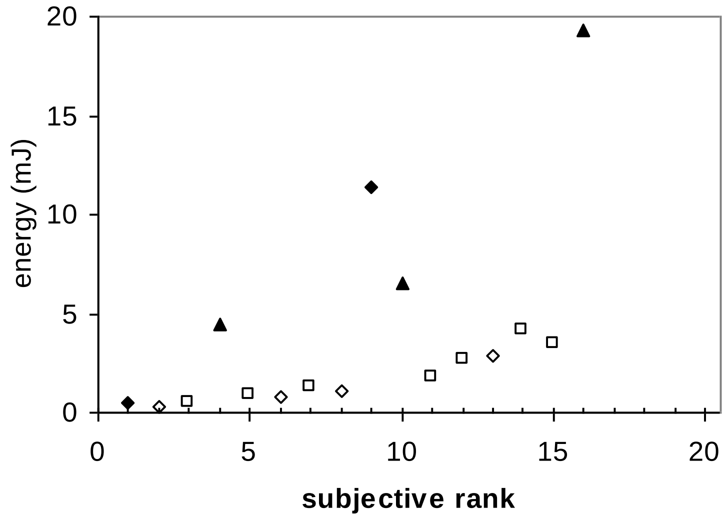


Figure 2. *Dissipated electrical energy in one 'momentary' stimulus plotted against ranking of subjective stimulus strength for collar E4a with 2 voltage pulses (open diamond), collar E3a with 3 to 6 voltage pulses (open square), collar E2 with 120 voltage pulses (solid square) and collar N2a with 136 voltage pulses (solid triangle) Only the first half of the N2a stimulus was used to ensure all stimuli were short.*

Because of the poor correlation between dissipated energy and rank, the energy calculation (1) was replaced by the more general relationship:

$$\text{Ranking indicator} = P^x.\int V(t)^y \, dt \quad (2)$$

The resistance R has also been removed from the calculation since measurements were made at a constant resistance. The calculation is therefore specific for a particular value of R. The best fit for the data available is obtained using this relationship with the values x = 0.6 and y = 2. As evident from Figure 3, the Pearsons correlation between the rankings of subjective stimulus strength and this ranking indicator is high at 0.98 and highly significant at p=0.001. Use of the number of pulses raised to the power 0.6 agrees well with data published by Notermans (1966). Since the resistance was constant, the current was proportional to the voltage, therefore the use of voltage raised to the power 2 is in agreement with Ekman (1964) and Rollman and Harris (1987).

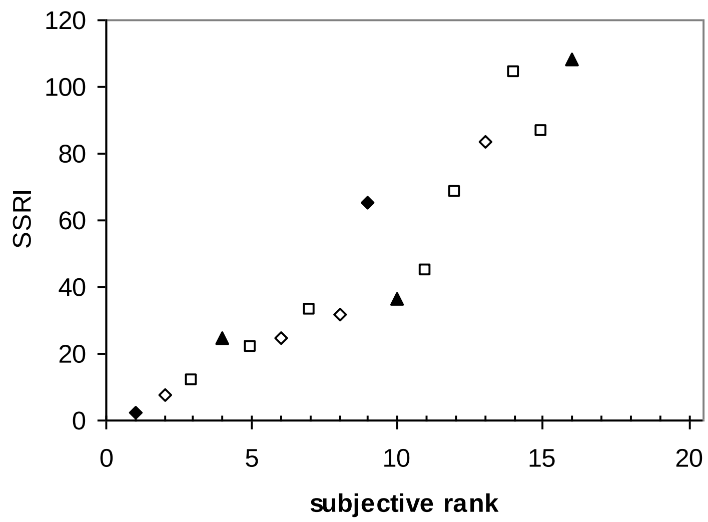


Figure 3. *Stimulus Strength Ranking Indicator calculated at an impedance of 39 kΩ plotted against the subjective rank of the stimulus strength for collar E4a with 2 voltage pulses (open diamond), collar E3a with 3 to 6 voltage pulses (open square), collar E2 with 120 voltage pulses (solid square) and collar N2a with 136 voltage pulses (solid triangle) Only the first half of the N2a stimulus was used to ensure all stimuli were short.*

Despite some remaining ranking consistencies, on the basis of this data fit and agreement with earlier work we therefore provisionally propose the use of a stimulus strength ranking indicator (SSRI) calculated as

$$\text{Stimulus strength ranking indicator SSRI} = P^{0.6}.\int V(t)^2\,dt \quad (3)$$

The measurements made on the e-collars and SSRI as calculated above (3) were used to compare the strength of momentary stimuli and one second continuous stimuli from each e-collar. The result of this comparison is given in Figure 4. Calculations are based on the measurements made using an impedance of 50 kΩ and compares both the maximum and the mid range level results. It is assumed that stimulus strength ranking calculation remains valid for stimuli lasting up to one second.

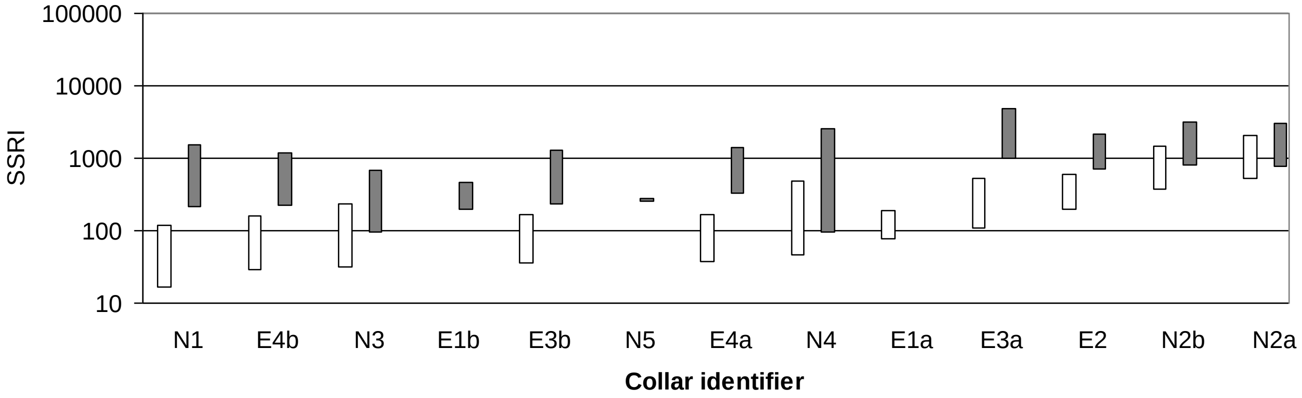


Figure 4. *SSRI of the momentary (open bar) and continuous (solid bar) stimuli for the 13 collar types tested, showing the stimulus strength of e-collars set to the mid strength level (lower end of bar) and to the maximum strength level (upper end of bar). Measurements made at an impedance of 50 kΩ and the 'continuous' stimulus is for 1 second.*

Figure 4 indicates a range in the e-collar stimulus strengths. For some, such as E2, N2a and N2b the mid range strength setting of the momentary stimulus exceeds the maximum strength available on other e-collars. Another difference between the e-collars is the relationship between the momentary and continuous stimulus. For six of the ten e-collar types where this comparison can be made, the predicted strength of a one second continuous pulse with the e-collar at its mid level setting exceeds the most powerful momentary stimulus that the collar is capable of generating. For the remaining four e-collars the predicted strengths of these two settings are broadly similar. If the difference in stimulus strength between momentary and continuous is as large as this analysis suggests, then some warning in the operation manual regarding relative strength of stimulus would seem to be prudent.

Discussion

The results from our small scale investigation show good agreement with previous work on the use of electrical stimuli as a scientific tool to assess detection and pain thresholds in humans. The SSRI may thus be used to compare different e-collars in a meaningful way. However, it must be emphasised that the results presented are based on a small sample of both human subjects and of electric stimuli and should be considered cautiously until validated in a larger test. In particular, the human literature (e.g. Laitinen and Eriksson 1985; Rollman and Harris 1987) indicates that there are considerable differences between subjects in perception of electric stimuli, and also the potential for contextual differences.

The method is nevertheless useful for comparing the outputs of e-collars, as well as being able to compare momentary and continuous functions. The SSRI approach suggests that stimulus strength of the collars that use a large number of voltage pulses is over-estimated by the dissipated energy metric. However, it should be noted that that though the electronic characteristics of an e-collar are undoubtedly important, this alone will not be enough to determine its impact on dog welfare, as this is also determined by the way in which it is used.

Conclusions from Objectives 1 and 2

The impedance of dogs can be modelled as a passive resistance with a value of about 10kΩ (10^{th} -90^{th} percentile range 4 – 150kΩ) for wet dogs and 600kΩ (22 – 950kΩ) for dry dogs. The impedance can vary considerably and apparently randomly from stimulus to stimulus even for the same e-collar on the same dog.

The 'momentary' stimulus generated by the e-collars comprised a sequence of identical short voltage pulses. The 'continuous' stimulus comprised a much longer sequence of the same voltage pulses. There were considerable differences between tested e-collar models in the voltages and the number of pulses in each stimulus.

The peak voltage delivered by e-collars varied significantly with the resistance of the dog, from as much as 6000v at 500kΩ to 100V at 5kΩ. The highest voltages are however applied for only a few millionths of a second. This variation in voltage ensures that the electrical energy dissipated remains relatively constant over a wide range of resistances. Values may be different for other e-collar models that were not included in the tests.

E-collars produced repeatable stimuli, with little difference from pulse to pulse and little difference from collar to collar within any given model. However different collar models exhibit significant differences in the electrical energy output of the stimuli between them, as well as in the energy relationships between momentary and continuous stimuli. It seems thus reasonable to advise users to assess the correct training level setting separately for the momentary and continuous stimulus.

There is an implicit suggestion in much of the trade literature that the strength of the electrical stimulus is related to the dissipated energy. This appears to be a flawed assumption. The scientific literature indicates that the effect of variation in the value of the resistance is inconsistent with the use of energy as a measure of stimulus strength, and our investigations indicate energy also fails to properly account for the effect of differing numbers of voltage pulses. We thus propose the use of a stimulus strength ranking indicator (SSRI). This does not enable comparisons of stimulus strength to be made where the resistance differs but appears to be more suitable than dissipated energy for comparing the stimulus strengths of different collar models. The SSRI showed there to be differences in stimulus strengths between the selected e-collars, as well as differences in the relationship between momentary and continuous stimuli.

One trade organisation (ECMA) specifies that collars should be tested to identify the maximum energy they put out over impedance range from 0.5kΩ to 100kΩ. This seems an appropriate test range, although a range from 4kΩ to 1000kΩ would be more relevant as this closely matches the impedance of dogs tested. The “fixed output current test” used by many manufacturers, however is specified for 0.5kΩ. Since this impedance is nearly an order of magnitude lower than that measured in dogs, our results suggest testing at higher impedances would be more relevant.

Manuals were clear on operation of the e-collar. All gave advice on setting the level of stimulation most suitable for the individual dog in training and included advice on the fit of the collar and the need to avoid irritation of the skin which might result in pressure necrosis. Statements referring to use on dogs over a certain age and health status were not always made. Manuals gave varying levels of information on the use of the e-collar in training. Most strategies tended to favour application of continuous stimuli during training until the dog showed the desired response.

For some e-collars stimulation was, or could be, automatically preceded by a tone, though all e-collars had the option of using the tone or vibration function independent of stimulation. Not all manuals adequately explained the potential use of tone and/or vibration functions in dog training. The emphasis of training advice in manuals was on the use of e-collars in obedience training, with only five out of nine assessed manuals including information on dealing with specific problem behaviours. However, only 3% of end-users surveyed in Section 4 reportedly used their e-collar for basic obedience training.

Information at the point of sale on e-collars is generally limited and does not allow meaningful comparisons between e-collars. Rarely does it give an indication of output characteristics of the device. Although a reliability assessment was not part of the examination, two faults were encountered in the level adjustment controls of two new e-collars, leading to stimulation at either a lower or the highest level.

Objective 3. Evaluate methods for assessing dog welfare in training context

The development and validation of methods to be used in the subsequent larger scale studies of the effects of e-collar training was the principle aim of Objective 3. This involved the recruitment of dogs with previous experience of e-collars and matched controls with no experience. Home visits to these dogs were arranged to assess the practicality and reliability of a range of tests. Previous studies of behavioural and physiological responses to arousing stimuli in dogs (e.g. Beerda et al 1998, Schilder and van den Borg 2004, Schalke et al 2007) and development of judgement bias tests, (e.g. Mendl et al., 2010) informed our methods, however as these had not been used in owned dogs within the domestic environment, a piloting stage was necessary prior to Objective 4 to assess their practicality. In addition, although a number of studies had sampled saliva for cortisol assay in dogs (eg Beerda et al 1998, Schalke at al 2007, Dreschel and Granger 2009), there was inconsistency in the timing of saliva collection relative to events under investigation and some variation in the saliva collection method. As a consequence two additional studies were conducted on staff owned pet dogs at University of Lincoln to investigate the effects of sampling technique on cortisol assay, and these are reported at the end of this section. These studies did not require a Home Office Project License, and methods were approved by institutional ethics committees.

Methods - Recruitment of Dogs and Overview of Protocol
Dogs used in the comparison of e-collars and their controls were recruited through a separately funded survey (Blackwell et al 2012). This involved distributing questionnaires covering a range of reward and punishment based dog training methods (thus including, but not specifically focussing on e-collar training) as widely as possible to dog owners at locations throughout the UK. Distribution was at dog related events, such as dog shows

or countryside events, and through pet stores, veterinary practices, and direct distribution to people walking dogs at popular locations. At the end of the questionnaire, owners were asked to supply their contact details if they were willing to become involved in a further study.

Those who had used electric training aids and provided consent were contacted by phone regarding further involvement, and to check dogs against inclusion and exclusion criteria. These were to establish that the dogs had only been trained with remote static pulse e-collars: dogs trained with invisible fences or other remote owner operated collars (e.g. citronella spray collars) were excluded. Subsequent to recruitment to the e-collar group, matched control dogs were identified from the available cases. These were matched by breed, sex and age group, and if possible by the undesirable behaviour for which the training method was used by owners. The main method of training, or training device used by each control case was selected as the focal training device. A total of 20 dogs were recruited, consisting of 10 dogs with prior experience of e-collar training and 10 matched controls.

Data were collected on visits to the owner's home and the location where the e-collars had been used if different from home (e.g. where the dog was walked). Visits were divided between researchers based at University of Bristol and University of Lincoln, split geographically. Joint visits were conducted during Objective 3 to check inter site consistency. Prior to visits, owners were sent consumables to collect dogs' first passage of urine on the morning of the visit and instructions on how to collect and store samples. The researchers aimed to arrive at a standard time (0900h), and after completion of consent forms, an initial saliva sample was taken. The urine sample was split into three aliquots if volume was sufficient, with one sample being fixed in acid to increase stability of neuro-transmitter metabolites, and then all were stored on ice. Data collection was conducted in the following order for each visit:

1. Owner collects and stores urine.
2. Initial saliva sample on arrival of researchers (hereafter, Saliva Sample 1)
2a. Split, fix and freeze urine samples.
3. First set of standard training tasks with the owner and researcher (hereafter, Standard Test 1)
4. Questionnaire completed about use of the focal training aid
5. Second saliva sample taken 20 minutes after first set of tests (hereafter Saliva Sample 2)
6. Owner fits the dummy collar
7. Dog allowed to habituate to the collar whilst second questionnaire completed
8. Second set of standard training tasks with the owner and researcher (hereafter, Standard Test 2)
9. Third saliva sample taken 20 minutes after the end of the tasks (hereafter Saliva Sample 3)
10. Dummy collar removed
11. Judgement bias task
12. Classical and operant learning task
13. Debrief

Questionnaire
Owners of dogs were asked to complete a questionnaire during the data collection visit. The questionnaire was used to collect the following data: a) general characteristics of dog and owner; b) information on how and why owners obtained e-collars compared to other training methods; c) information on timing and number of training sessions; d) owner perception of their dogs' response to the first and subsequent use of focal training devices, e) owner perception of success and outcome of training; and f) characteristics of e-collars used.

Urine cortisol; creatinine and urinary neurotransmitter metabolites
Dog owners were sent instructions and containers for first passage urine to be collected on day of visit. Owners were asked to collect 10ml of urine using a disposable cardboard urine tray, transfer contents to a sealable 100ml tube and store tube in their domestic refrigerator. On arrival researchers pipetted urine in 0.5ml aliquots into up to three 5ml vacutainers, one of which contained 0.05ml hydrochloric acid (HCl) (32%) to stabilise neurotransmitter metabolites. Where less that 1ml of urine had been collected analysis of urinary cortisol was prioritised. and as a consequence sample sizes for assays of neuro-transmitters were lower than those for urinary cortisol. These were stored on ice (or on dry ice if not returning to lab on the same day) and transferred to -80 centigrade freezer prior to analysis of neuro-transmitter metabolites by HPLC at University of Bristol. The remaining urine was transferred into 2x30ml plastic tubes. Both samples were frozen at -18 centigrade on return. One sample was sent away to Axiom Laboratories for cortisol/creatinine analysis using ELISA and the other was retained as a back-up.

Salivary Cortisol
Saliva samples were collected by encouraging salivation with food treats, and inserting a cotton epaulet mounted on a long handle into the space between dogs' cheeks and teeth (Beerda et al 1998). Saliva samples were collected from dogs at three time points during visits:
1. Sample 1: as soon as possible after arrival (usually within 5 minutes but longer in some cases)
2. Sample 2: 20 minutes after completing all sub-tests of the first set of standardised tests (with no collar)

3. Sample 3: 20 minutes after completing all sub-tests of the second set of standardised tests (with dummy collar)

Standard training tasks and collar fitting

Dogs were observed whilst undertaking 3 standard training tasks ('stay', 'recall' and 'leave', selected as commonly trained behaviours) plus one task for which the focal training device or method had been specifically used by the owner. Each dog was tested four times in total: initially without wearing a collar and trained separately by owner and researcher, and then when wearing a collar with both owner and researcher. Owners were asked to use the e-collar (turned off) that they had used in training, but if this was no longer available, a dummy collar which could not deliver a stimulus was provided by the researchers. The dummy collar was used for the control population. To investigate the occurrence of behavioural signs on fitting the collar, the behaviour of each dog was recorded as the owner fitted the collar and for a period of one minute afterwards. Behavioural data was collected on video and analysed using Observer software. Three types of behavioural measure were recorded.

1. Individual behaviours
2. Holistic behavioural 'state' according to pre-defined criteria (Table 6)
3. Immediate response to commands given.

Behavioural state	Definition
Tense	Dogs shows a combination of: tense facial posture (muzzle tight), ears back or down, tail held stiffly or between legs, lip licking, rapid jerky head movement
Relaxed	Dog shows slow, relaxed movement with no tension in face or muzzle
Excited	Dogs shows a combination of: rapid or jerky movement, jumping, panting, ears forward, tail high or wagging, play signals
Anticipatory	Dog shows intense focus on a person or task, for example waiting for a command, with ears forward and direct gaze
Ambiguous	Dog clearly displays a mixture of 'tense' and 'relaxed' or 'excited' behavioural signs
Unknown	Dog is not visible, video recording is unclear, or the behaviours of the dog cannot be clearly interpreted

Table 6: *Definitions of 'composite' behavioural variables used in collar fitting and standard training tasks observations.*

Judgement bias task

The project used a spatial discrimination task as developed by Burman et al (2008) in rats and subsequently used to investigate judgement bias in dogs by Mendl et al (2010). During training, dogs discriminated between two locations in which a plastic bowl could be located: in one location the bowl was baited with food, in the other there was no reward. (Figure 5). Placement and baiting of bowls was unseen to dogs and auditory/olfactory cues controlled.

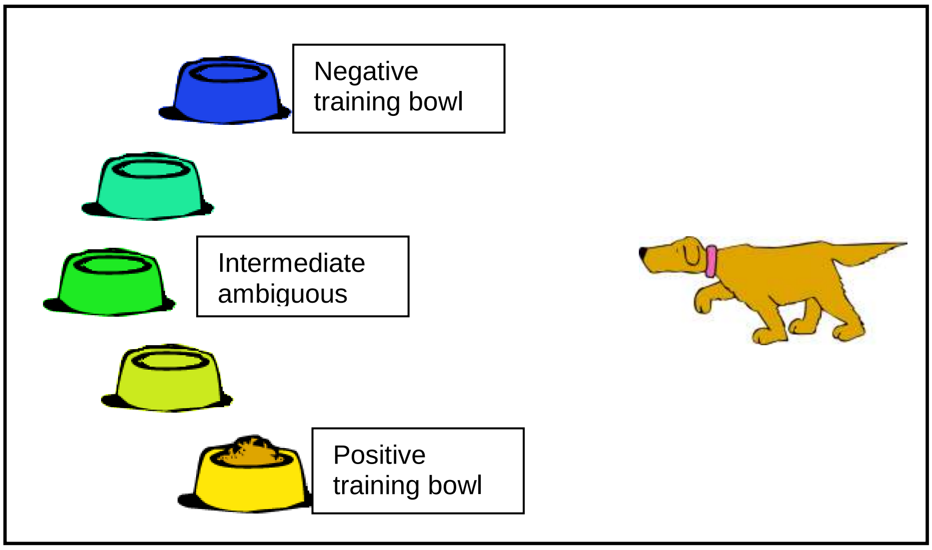


Figure 5: *Schema of judgement/cognitive bias task. Dogs are trained that outer positions will either be a positive training bowl containing food, or a negative training bowl containing no food. Speed of approach to intermediate probes was measured once dogs were approaching the training bowls with consistent speeds.*

Once the training criterion was reached (where the speed to the positive location was consistently faster than to the negative on six consecutive presentations), dogs moved to the test phase. Here dogs were presented pseudo-randomly with ambiguous 'probe' trials, where an empty bowl was positioned in one of three positions – central between positive and negative locations ('middle probe'), between the centre and positive location ('near positive probe') and between the centre and negative location ('near negative probe'). The rationale behind using this test was that the extent to which an individual animal perceives the intermediate probes as likely to be 'positive' (i.e. baited) or not reflects their internal emotional state. Hence, animals in a more negative emotional state may be more pessimistic about achieving a reward and less likely to run to an intermediate probe than one that is in a positive state. Previous studies (e.g. Mendl et al. 2010) used a standard test area size with negative and positive training bowls 4m apart and all bowls placed 3m from the dog's starting position and this layout was planned for the tests conducted during Objective 3.

Classical and Operant Learning tasks

The level of arousal can affect the speed with which animals form and retain new associations. Moderate levels of arousal lead to the swifter conditioning of adaptive behavioural responses, whilst high levels of arousal, or chronic distress can slow learning rates and interfere with memory formation (Laughlin and Mendl 2000, Bodnariu et al. 2006). In Bodnariu et al. (2006), dogs in a rescue shelter were trained to make a classical association with a novel stimulus, and then to learn a novel operant task. The speed at which dogs learnt these tasks was associated with measures of urinary cortisol:creatinine. Investigations of learning speed and retention, therefore have potential to provide independent measures of underlying physiological state as well as learning speed.

This section involved training dogs to associate a novel buzzer sound with a food treat (cheese for 10 dogs, ham for 3, sausage for 1, and dry food for the remaining 4 dogs) and then using this conditioned reinforcer to train the dogs to touch the tip of a novel object through three stages of shaping.

Measures compared between the control and e-collar groups were:

- Total trials needed to reach criterion for classical association
- Time taken to learn the classical association
- Total time to complete the task
- Whether dog touched object on first encounter

Results from Objective 3.

A large number of measures were collected in Objective 3, and consequently there was considerable potential for Type 1 errors. However the aim of this objective was not to determine differences between the two populations, but rather to assess the suitability of the measures chosen for the test situations and as an aid to estimating sample sizes for the larger Objective 4. For this reason, analysis are presented without the Bonferroni corrections, or multi-variate approaches used in Objective 4 for their descriptive value, and should not be taken as indicative of treatment effects. Power statistics for two sample comparisons were used to provide indications of sample sizes of sufficient power for Objective 4.

Assays for salivary cortisol appeared elevated at the first "baseline" sample, (2.99±0.58ng per ml) compared with 2.61±0.37 on sampling between first (no collar) and second (collar) standard command tests and 2.84±0.62 on sampling after the second (with collar) set of standard commend tests (Figure 6). This was however not significant ($F_{2,34} = 1.77$, $p > 0.05$). Control dogs appeared to have reduced salivary cortisol measures between test 1 and test 2, and e-collar dogs had an increase (Figure 6), but there was no overall significant effect of group ($F_{1,34} = 1.95$, $p > 0.05$) nor interaction between group and sample ($F_{2,34} = 0.63$, $p > 0.05$) at the sample size used in these pilots. Nevertheless the treatment effects were relatively large, indicating that the larger sample sizes (n = 60 for both control and e-collar groups) should have sufficient power to assess treatment effects with high statistical confidence.

There was no significant difference in cortisol:creatinine ratio from first passage urine ($t_{18} = 0.25$, $p > 0.05$) between the control dogs (Mean±SE of 14.5±1.5) and the e-collar dogs (13.7±2.9). No differences were found between dogs in the e-collar group (13.0 ±4.5umol per l) and control group (14.3±4.2) for HVA concentrations, nor for 5-HIAA concentrations (e-collar: 20.0±5.6 vs control 14.8± 2.2).

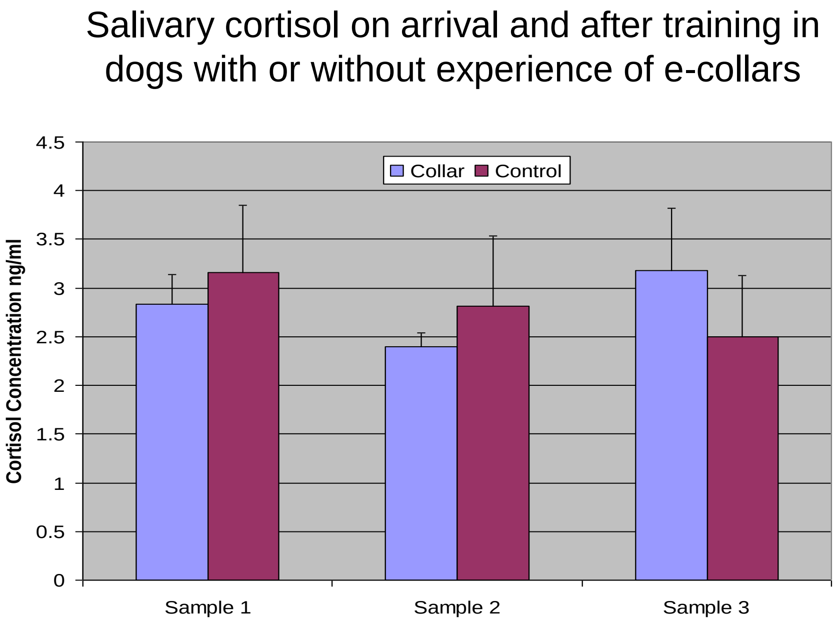


Figure 6. Salivary cortisol (mean ± SE) from E-collar experienced and matched control dogs at sample 1 (on researchers arrival), sample 1 (after training without a dummy e-collar), and sample 3 (after training with a dummy e-collar) during pilot studies (n = 10 for control and e-collar groups)

Standard training tests

A mixed between-within subjects analysis of variance was conducted to investigate relationship between group (control/e-collar) and change in behaviours from the first test (without the collar) to the second test (with the collar). These analyses were conducted separately for pairs of tests conducted by the owner and researcher.

An interaction was found between group and test with respect to the proportion of time that dogs maintained a distance of less than 5m from the researcher during training (Wilks' Lambda = 0.742, $F_{1,15} = 5.208$, $p < 0.05$, eta squared = 0.258). No significant interaction between test and group was found with respect to distance from owner during testing, although there was a significant overall effect of group, with e-collar dogs being more likely to spend more time at least 5 metres away from their owners ($F_{1,18} = 6.456$, $p < 0.05$, eta squared = 0.264). Although no significant interaction was found between group and change in lip licking between tests when the owner was training, lip licking did occur for a greater proportion of time overall in the control dogs with their owner ($F_{1,18} = 5.002$, $p < 0.05$, eta squared = 0.217). In addition, there was an overall significant increase in proportion of time spent lip licking between tests 1 and 2 when the owner was training (Wilks' Lambda = 0.803, $F_{1,18} = 4.411$, $p = 0.05$, eta squared = 0.197).

Similarly, no interactive effect was found for the proportion of time that dogs were active during the training tasks with their owner, but a significant overall effect of group was found ($F_{1,18} = 9.702$, $p < 0.01$, eta squared = 0.350), with e-collar dogs being significantly more active. An overall effect of group was also found with respect to the proportion of time that dogs were distracted when being trained by the researcher, with e-collar dogs being more likely to be distracted ($F_{1,15} = 5.181$, $p < 0.05$, eta squared = 0.217). There was also a trend for level of distraction overall to decrease in the second test (with collar) across all dogs (Wilks' Lambda = 0.772, $F_{1,15} = 4.427$, $p = 0.053$, eta squared = 0.197). There was, however, no significant interaction between change in distraction and group.

The proportion of time that dogs showed a tense body posture when the researcher was training was also different between groups, with control group dogs showing significantly more overall ($F_{1,15} = 4.688$, $p < 0.05$, eta squared = 0.238). There was, however, no effect of test, nor any interaction between test and group. A within-subjects effect was found for the proportion of time that dogs showed attention to their owners, an overall significant increase occurring at the second test compared to the first ($F_{1,17} = 42.092$, $p < 0.001$, eta squared = 0.712). However, no significant effect or group, nor interaction with group, was found.

Behaviour during collar fitting

Dogs in the control group were significantly more likely to sniff the collar (Mann Whitney U, Z = -2.142, $p < 0.05$) than in the e-collar group. There was no significant difference between groups with respect to sniffing the environment. Dogs in the control group were also significantly more likely to show attention seeking behaviours than those in the e-collar group (Mann Whitney U, Z = -2.289, $p < 0.05$). Dogs in the e-collar group were more likely to shake themselves during collar fitting Mann Whitney U, Z = -1.979, $p < 0.05$). Although not significant, there was also a trend for dogs in the e-collar group to show an increased proportion of time panting, and a greater number of other oral behaviours (licking nose and lip, yawning and opening mouth) than those in the control group.

Cognitive bias task
The un-scaled running speeds to the positive and negative locations and three intermediate probes, for the dogs in the pilot study, are shown in Figure 7.

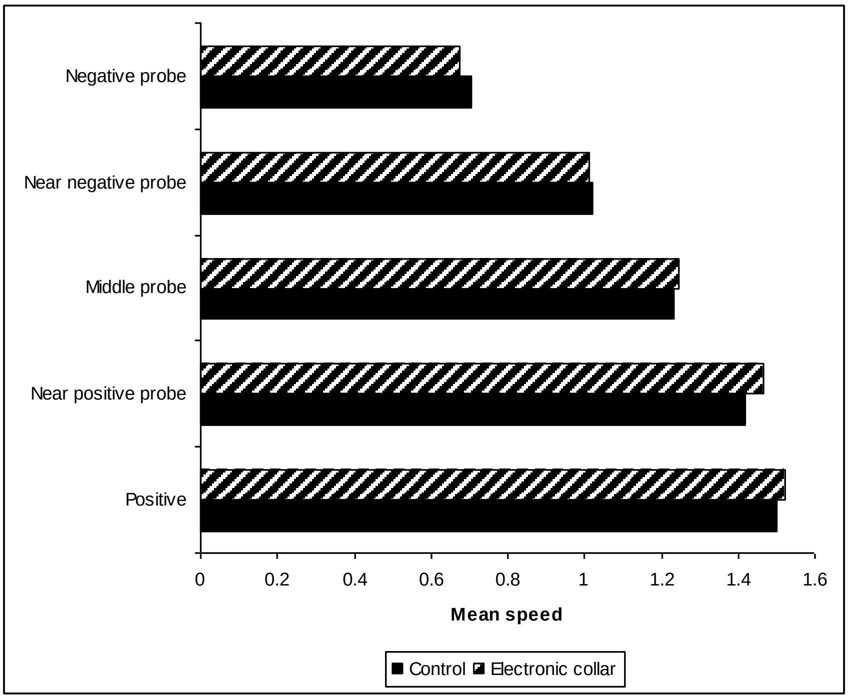


Figure 7 Unscaled speeds to reach positive and negative locations and intermediate probes split by group (e-collar or control)

Because the dogs were different sizes, their speed to reach the probes was scaled to account for their baseline running speed. Scaling the data was done using the following formula:

$$\frac{\text{Mean speed to reach ambiguous probe – Mean speed to reach positive}}{\text{Mean speed to reach negative – Mean speed to reach positive}}$$

No significant difference was found between dogs in the e-collar and control group for scaled running speed to any of the probes. Despite there being no significant differences between groups for this test, the cognitive bias test was retained in the protocol due to interest in this novel test and the potential for investigating data from a larger sample size.

Classical and Operant Learning Task
None of the behavioural measures recorded during training of novel tasks were significantly different between the e-collar and control groups, although some trends were apparent. For example, the dogs in the e-collar group tended to take longer to learn both the classical and operant task than those in the control group. However, despite taking longer, dogs in the e-collar group tended to make less touches of the cone during the training task. Other behaviours of the dogs measured during this task were the frequency of licking lips, lifting a paw, looking at the researcher and vocalising. There were no significant differences between groups for these behaviours.

Additional Pilot Studies
In addition to developing and evaluating the practicality of applying the methods to be used as part of objective 4 in a training context, the pilot stages of the project also involved two studies of secretion of salivary cortisol, as a means of validating the methods to be used in saliva sampling. Specifically these were an investigation of the use of food lures to facilitate saliva sampling, and the sequential sampling of saliva to determine appropriate sampling times post training.

Salivary cortisol has been widely used as a means of assessing stress in dogs (Beerda et al 1988; Schalke et al 2007), though several authors have questioned whether handling and the use of food/chews can affect measures

(Kobelt et al 2003, Dreschel and Granger 2009). We investigated effects of food on salivary cortisol measures in a handling/training context.

For the first study 10 dogs were used to investigate if food introduced unpredictable variation in salivary cortisol. For each dog tested, a control sample was taken, followed within 30 seconds by a sample with cheese (n=10), sausage (n=5) or chicken (n=5). Cortisol assayed with food tended to be lower (2.14±0.12ng/ml) than controls (2.59±0.23; t=2.08, $p<0.05$). This may be due to dilution of samples by greater production of fluid, or because food contamination reduces the efficacy of ELISA. There was a high positive correlation between the measures from cheese samples and their controls (Pearsons r=0.922, $p<0.001$), but no evidence of correlation with the sausage and chicken.

In the second study, we used cheese to encourage salivation and 10 dogs were used to investigate changes in salivary cortisol following training similar to the standard training tests already described. Dogs responded to three common vocal commands; "come", "stay" and "leave", together with a fourth command of the owner's suggestion, each given by the owner, and by a person unfamiliar to the dog. Saliva was sampled before training, then at 10, 15, 20 and 25 minutes following start of training. There was no difference in salivary cortisol measures between samples, but a high concordance across samples (Kendall's W=0.858, $p<0.001$).

Our data suggests cheese does not introduce unpredictable variation is salivary cortisol measures, and consequently may be a more appropriate aid to encourage salivation than sausage, chicken or meat flavoured rope (Dreschel and Granger 2009).

Discussion and Conclusions from Objective 3

During this objective we assessed the practicality and conducting a large number of diverse data collection methods on dogs and their owners. These included collecting data via questionnaire, requiring owners to collect and store first passage urine, collecting saliva before and after training sessions, video recording behaviour during collar fitting and training sessions, and finally two learning tasks, the first to assess cognitive bias, the second to assess speed on learning. The majority of data collection was conducted in the owner's home, though where appropriate dogs, owners and researchers would also travel to a separate location where the standard learning tasks were conducted. This was a potentially long period of data collection taking about 2 hours if no delays were encountered with a number of approaches that needed to be consistently applied, some of which were reliant on owner compliance, whilst the majority needed to be applied consistently by the two research teams. Standard Operating Procedures (SOPs) were drawn up at the start of the study, and these were reviewed at the end of Objective 3. As part of this assessment a number of visits were jointly conducted by the Lincoln and Bristol teams to assess understanding and compliance with protocols.

A small number of changes were implemented from original proposal. These being the addition of the collar fitting observation, a short video recording of the dogs' immediate response to the fitting of the dummy collar between standard tests 1 and 2. This was added as a small number of dogs had shown relatively extreme responses to dummy collars. The other major change was the removal of the final learning tasks. There were signs of fatigue in dogs, owners and/or researchers by the end of the visit, and there were concerns this may lead to problems in application and interpretation of results, so the final learning task was removed for objective 4. Data on learning speed could be accessed from the cognitive bias tasks as these involved the acquisition of a novel position based discrimination, prior to investigating responses to probes.

A number of inconsistencies were noted from the pilot studies. Firstly there was potential for variation in storage of urine, as owners placed samples in domestic refrigerators (that may vary in temperature) rather than freezers prior to arrival of research team, a problem that could be exaggerated if research team failed to reach owner by 0900h. This was a potential problem for assays of neurotransmitters metabolites which needing fixing with HCL and freezing to prevent degradation of sample. Asking owners to fix a proportion of the sample using HCL and then freeze was rejected for reasons of safety as well as the risks of losing urine for the higher priority cortisol:creatinine assay. The instructions to owners were therefore tightened to indicate they should set fridge at low setting, minimise opening and record time of sample, and research teams reviewed journey planning to ensure they arrived at owners at consistent times.

For cognitive bias tests a 4m by 3m test had been selected as this had been used in previous work (e.g. Mendl et al 2010), however, many owners did not have as large a free space in or near their homes. We had considered standardising the tests by for example moving the dogs to a larger area away from the home environment, but previous experience developing and piloting the cognitive bias test at the University of Bristol suggested that testing in an unfamiliar environment introduces more uncontrolled variables/distractions than the familiar home environment. To enable recruitment of dogs without adequate space for a 4m X 3m arena, reduced arena sizes were used by one research centre, with the aim of adjusting for running distance through use of speeds rather than latencies to probes on analysis.

As an overall conclusion, owners were happy to comply with data collection, and the majority of tests could be conducted over practical timeframes, especially when the final learning tasks were removed. The aim of this part of the study was not to test for treatment effects, but rather assess the potential value of measures and suitability of planned sample size for the larger study that would make up Objective 4. There was evidence of treatment effects in both the behavioural and the physiological data in response to the standard training tasks. The size of these treatment effects in the pilot study suggested that the sample sizes planned in Objective 4 would have sufficient power to evaluate the impact of prior experience of e-collars on responses to training tasks for a number of behavioural measures that may be associated with negative emotional state and for physiological measures such as salivary cortisol. Other measures such as urinary cortisol, neurotransmitter metabolites and the cognitive bias scores showed little evidence of treatment differences. Following discussion with defra, these measures were collected as part of objective 4 as they had potential to provide valuable background information on the make up of the two treatment groups.

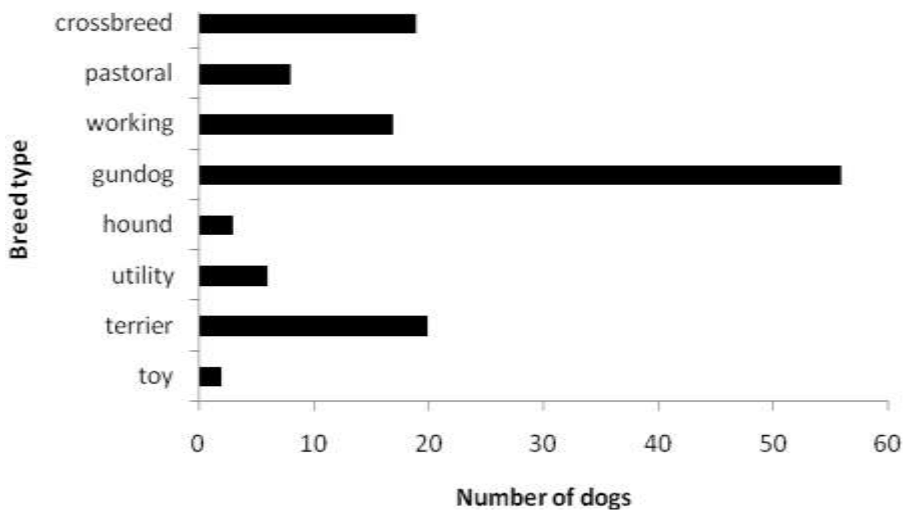
Objective 4: Investigation of the long term behavioural, physiological and psychological effects of using training devices on the domestic dog in a case-control study design

The aim of Objective 4 was to evaluate the consequences of e-collar training using a range of behavioural and physiological measures. The rationale behind the comparison of dogs with experience of training with e-collars and control dogs with no such experience was that the use of e-collars for training will influence subsequent behavioural and physiological responses by the dog, particularly in situations similar to that in which collars had previously been used by owners. Data collected from this study will be presented in three sections. Section 1 will cover the sample description and the data derived from owner questionnaires. Section 2 will focus on behavioural and physiological measures (salivary cortisol) associated with the standard training tasks. For these two sections data from an additional 11 controls recruited to assess order effects during the standard tests are presented in addition to the e-collar dogs and their controls. Section 3 will include other data collected just from the c-collar dogs and their controls including behaviour during collar fitting, the remaining physiological data and the findings of the cognitive bias tests.

Section 1: Questionnaire Results

The majority of dogs (n=94) were recruited from the training survey (Blackwell et al 2012), though other sources were used to recruit dogs by one research centre including a separate online questionnaire (n=9), a call for evidence about the use of e-collars issued by the Companion Animal Welfare Council (CAWC) (n=19), personal contacts of the researchers (n=19) and via other participants (n=3), to increase sample sizes. A total of 144 visits were completed (66 e-collar, 78 controls) and full owner interviews were completed for 131 of the dogs (66 e-collar dogs and 65 control dogs). For the e-collar and control groups, slightly over half of the dogs (n=70; 53%) were male. The ages of the dogs ranged from 6 months to 12 years, with a median age of 38 months. The majority of dogs were young adults, with 63% (n=83) of dogs recruited aged between 2 and 6 years. The remainder were 6 months to less than 2 years (n=23, 17.5%), 6-10 years (n=19, 14%) and over 10 years (n=6, 4.5%). Nineteen of the dogs were crossbreeds (a mix of two or more breeds), with the remainder being purebred dogs, as shown in Figure 8.

Fig 8: *Breed types of dogs used in study, as categorised by UK Kennel Club*



The criteria by which cases and controls were matched were compared using chi-square tests to verify the matching process. Other characteristics of the sample were compared between groups using logistic regression. Univariate screening was conducted of all potential predictive variables, and possible interaction factors. Those significant at P<0.2 were included in the multivariate model. The best fit model was obtained using a backward stepwise approach, where the effect of removing each variable on the deviance of model was individually evaluated. Separate models were constructed to identify differences between groups with respect to behavioural signs reported by owners on use of devices, and for owner perceptions of training outcomes. Where variables could not be included in regression models due to complete separation (i.e. zero cases in one group), separate univariate analysis using Chi-squared tests were used, with Bonferroni adjustments for significance levels. Data from owner responses in free answer sections of the interview was reported descriptively.

The majority of owners were female (n=94; 72%). Eleven owners (8%) were under 25 years, 25 (19%) were between 25 and 40 years, 55 (42%) were between 41 and 60 years, and 20 (15%) were over 60 years. Age was unknown for 20 (15%) of owners. Comparisons between e-collar and control groups for criteria used to match groups suggested that matching had been successful. There was no significant difference between the sex of dogs in the e-collar and control groups (χ^2=0.009; df=1; p=0.925), and no significant difference between the ages of dogs in the e-collar and control groups (Mann Whitney U, Z= -0.924; p=0.355). Groups were also well matched for breed type (χ^2=3.525; df=7; p=0.833).There were eight different types of devices and training methods used by owners in the control group: 60% of owners in the control group had primarily used positive reinforcement techniques, including food rewards (n=18), verbal praise (n=5), clicker (n=9) and whistle (n=7). The remaining 40% of owners in the control group were assessed as having used primarily negative reinforcement and/or positive punishment approaches to address the obedience or behavioural problem including use of head collar or harness (n=15), rattle-tin (n=6), water-pistol (n=1), choke or check chain (n=4). Only 2 owners from the e-collar group reported using the e-collar for general training of their dog: the remainder used them as a treatment for specific undesired behaviours. Although used for a range of behaviours, almost half of these owners (46%, n=30) reported that they had used the e-collar to improve their dog's recall (Table 7) and a further 22 dogs (33%) used e-collars to address chasing.

Table 7: *Type of problematic behaviour for which the e collar was used, as reported by owners*

Type of behaviour	**Number of owners**	**% of owners**
Recall	30	46
Chasing	22	33
Aggression	4	6
Obedience training	2	3
Coprophagia	3	4.5
'Leave' training	2	3
Jumping up	1	1.5
Pulling on lead	1	1.5
Destructive behaviour	1	1.5

On univariable screening, the following variables were non-significant at P<0.2, and not included in the regression model: owner gender, owner age category, where the owner first heard about the focal device, why the owner followed recommendation to use the device, whether the device was used for behaviours other than that for which it was originally acquired, where the device was used and whether the device had been used by someone other than the owner, and how often the behaviour for which the device had been used occurred. Thus, included in the multivariable model were: how the owner was recruited to the study; whether or not the device was recommended to the owner, the reason (type of behaviour) for device use; whether the device appeared to be used according to the guidelines for use (judged by researcher); owner perceived severity of the behaviour; whether the device was used when the dog was on or off the lead; whether other techniques had been used previously for the same behaviour; how long ago the device was first used; how long ago the device was last used; and the time period over which training took place. All interaction factors were non-significant at P<0.2, except for the interaction between type of behaviour and owner perceived severity of behaviour and the interaction between type of behaviour and whether other techniques had been used previously, both of which were included in the model.

Table 8: *Variables included in the final model comparing characteristics of the e-collar and control device groups.*

Variable	Category	Wald statistic	df	P value	Odd's Ratio (OR)	95% CI for OR	
						Lower	Upper
Type of behaviour for which device was used	Reference: Recall / chasing	19.837	2	<0.001			
	Other undesired behaviours	17.734	1	<0.001	0.031	0.006	0.156
	General / obedience training	9.826	1	0.002	0.049	0.008	0.324
Owner perception of behaviour severity	Severe compared to reference of less severe	12.684	1	<0.001	15.709	3.450	71.518
Dog on or off lead during device use	Off lead only compared to reference of on lead or both	3.485	1	0.062	3.743	0.936	14.965
Was the device used according to instructions	Yes compared to reference of no or don't know	2.489	1	0.115	0.348	0.094	1.291

The variables retained in the final model (χ^2=81.243, df=5, P<0.001) are shown in Table 8. The model explained between 53.9% (Cox and Snell R^2) and 72% (Nagelkerke R^2) of the variance between groups. Whether the device had been used correctly (as judged by researcher) and whether the device had been used with the dog on or off the lead were retained in the model despite P>0.05 as removal affected model deviance more than expected for associated degrees of freedom.

The model used to compare owner report of dogs' response to focal device use included behavioural responses reported by owners on first use, and subsequent use of the training device. On univariable screening, the following variables were non-significant at P<0.2, and were not included in the regression model: did the dog run away on first use of the device; did the dog tremble on first device use; did the dog stop and sniff on first device use; did the dog have its tail between its legs on first device use; did the dog shake its head on first device use; did the dog react differently to the owner after first use of the device; did the dog run away when the device was put on in subsequent training sessions; did the dog have its tail between its legs on fitting the device in subsequent training sessions; did the dog become excitable on having the device fitted in subsequent training sessions; did the dog become interested and attentive on fitting the device in subsequent training sessions; did the dog try and remove the device on fitting in subsequent training sessions, and did the dog run away on use of device in subsequent training sessions.

Included in the multivariable model were: did the dog stop and look around on first device use; did the dog show interested / attentive behaviour on first device use; did the dog back away / be reluctant to have device put on in subsequent training sessions; did the dog show no reaction to device on use in subsequent training sessions, and did the dog show interested and attentive behaviours on subsequent device use. The variables retained in the final model (χ^2=54.381, df=3, P<0.001) are shown in Table 9. The model explained between 40.1% (Cox and Snell R^2) and 53.7% (Nagelkerke R^2) of the variance between groups. The variable for no occurrence of a behavioural reaction on subsequent use of the device was retained in the model as removal affected model deviance more than expected for associated degrees of freedom.

Table 9: *Variables retained in final model for behavioural responses reported by owner on device use*

Variable	Category	Wald statistic	df	P value	Odd's Ratio (OR)	95% CI for OR	
						Lower	Upper
Dog stopping activity and looking on first use of device	Yes compared to reference of no	14.140	1	<0.001	10.526	3.086	35.901
Dog showing interested and attentive behaviour on subsequent use of device	Yes compared to reference of no	10.545	1	0.001	0.068	0.013	0.344
Dog showing no reaction on subsequent use of device	Yes compared to reference of no	3.415	1	0.065	0.260	0.062	1.085

Two variables had complete separation as no dogs in the control group showed the behaviour and hence could not be included in the regression model. Both were significantly greater in the e-collar group using a Bonferroni adjusted P value for three separate analyses (P<0.017). These were vocalising (bark, whine or yelp) on first use of device (e-collar n=21, control n=0, χ^2=22.074, df=1, P<0.001) and vocalising on device use in subsequent training sessions (e-collar n=14, control =0, χ^2=10.760, df=1, P=0.001)

The final model compared owners' subjective experience of using the focal training device between groups. On univariable screening, the following variables were non-significant at P<0.2, and not included in the regression model: has the device changed the owners' relationship with their dog; was the device successful for training the specific behaviour; how much of an effect on the dogs' behaviour did the device have; did the device use result in any new behaviours; has the dog become easier to train; whether owner would use the device again. The final model (χ^2=7.850, df=1, P=0.005) only included whether owners would prefer to use a different training techniques if they knew more about training (yes compared to no; Wald = 7.358; df=1; P=0.007, OR = 3.224, lower 95%CI for OR = 1.384; upper 95% CI for OR = 7.513).

Discussion of Questionnaires

The survey of owners indicated that control and e-collar groups were well matched for age, sex and breed type of dog, though owners reported a greater severity of problem for e-collar trained dogs. Because the rating of severity was based on owner report, it is not possible to accurately determine whether the dogs trained using e-collars actually had more severe behaviour problems (with respect to ease of resolution) than those trained using other methods. Apart from the problem of interpreting the relative severity of very different types of behaviour, the degree to which owners consider a behaviour to be a problem may not be related to its frequency or the degree to which the behaviour is established, rather on owner perception as to what is difficult, embarrassing or impacts on their lifestyle. This score could therefore indicate either that e-collars tended to be used for more severe problems, or that the people who chose to use e-collars were less tolerant of particular undesired behaviours. Within the e-collar group, 79% of dogs were trained for recall (46%) or recall related (33% livestock chasing) problems. It is interesting that although owners in e-collar and control groups considered the focal device to be equally successful, e-collar users were more likely to report that they would prefer to use a different method. This may reflect their perception of the severity of their dogs' behaviour, and that e-collar use is a 'last resort' or "necessary evil", or may be associated with their perception of how their dogs reacted to stimuli. Furthermore, owners using positive reinforcement during training were more likely to report that their dogs had become easier to train, and less likely to state that they would prefer to use a different training method than owners in the other groups. This may reflect again broad owner perception about the 'acceptability' of different training techniques and their experiences of the dog's behaviour during training.

E-collar brands used by owners were representative of the range of models available, though only 2/3rds of e-collar users bought new collars with many owners borrowing e-collars, or acquired them second-hand. Many owners found it hard to recall how they had used the collars or to describe how the collar should be used, even when training had been relatively recent. Owners were particularly unclear about how they had habituated their dog to the e-collar, how they had decided upon what level of stimulus to use and whether or not the stimulus was preceded by a tone or vibration warning. The acquisition of second-hand devices may mean that training manuals and other instructions for use were not available with the devices, although many brands have such advice available on their web-sites. The review of literature available to e-collar users in Objective 2 suggests that whilst manufacturers generally provide clear information on the operation of the device, some provided little information on resolving common problem behaviours. Consequently even owners purchasing new e-collars may not be aware of best practice in addressing specific behavioural problems. There was considerable variability in how owners reported setting intensity levels or using tones on the devices. All manuals that accompanied e-collars assessed earlier in this report included at least a sentence on finding the right training level for each dog, which suggests that some end-users either fail to read instructions, misunderstand or deliberately disregard the advice in the manuals.

Most owners reported that their dogs stopped and looked around on first and subsequent use of e-collars, which could be consistent with the advice in finding the right level. However, some end-users reported starting at the highest level and adjusting downwards or always training using the highest level. The finding that 36% of owners reported that dogs trained with e-collars vocalised when the device was first used was higher than might be expected from the advice given in e-collar manuals and could be a cause of some concern as it indicates that the devices may not be used correctly. However, the finding that 26% of dogs were reported to vocalise on subsequent use may be of more concern as it indicates that the training levels used are too high in these cases. Due to the differences in the way the e-collars were reported to have been used it is likely that different dogs have very different experiences of training with these devices. Some of the reported use was clearly inconsistent with advice in e-collar manuals and potentially a threat to the dog's welfare. It is likely that different individual dogs have very different experiences of training with e-collar stimulation.

Section 2. Behaviour during standard tests
Data collection and Analysis
Individual behaviours and composite holistic measures were recorded from video recordings of standard tests by a blinded researchers using Observer software. Mean inter-observer reliability (Cronbach alpha) for behavioural measures was >0.7, hence measures from observers were combined. Each variable was recorded for each of the four subtests (i.e the 'leave', 'recall' 'stay' and specific behaviour trained with the focal device) both with the owner and researcher, and then repeated with dogs wearing a dummy collar. Individual measures included 15 composite variables (Table 6); run, walk, stand by owner, stand by researcher, stand elsewhere, sit by owner, sit by researcher, sit elsewhere, lie down by owner, manipulate object (leave subtest only), manipulate toy, manipulate something else in environment, sniff object (leave subtest only), sniff something else in environment, social interaction; and 12 behavioural events; play bow, lick lips, yawn, bark, whine, other vocalisation, shake body, jump up at owner, jump up at researcher, urinate or defecate, lift paw, and roll over. All 27 variables were measured for the 'leave' subtest, and 25 for the remaining 3 subtests, giving a total of 408 variables.

Data reduction. Data reduction was conducted separately for the first test, with no collar (T1), and second test where the dog was wearing a collar in the e-collar and control groups (T2) but not in the extra controls. Since behaviours did not significantly vary between sub-tests, mean behaviours were calculated for the subtests completed by each dog. The frequencies of mean variables for each situation were examined, and those occurring in less than 10% of cases across the four situations were either removed or combined. The following variables were removed: 'Play bow'; 'Yawn'; 'Bark'; 'Whine'; 'Other vocalisation'; 'Urinate or defecate' and 'Roll over'. 'Manipulating and sniffing the object used in the leave test', and 'Manipulating or sniffing other objects in the environment' were combined as 'Explore'. Other behaviours shown by dogs independent of the training process ('Manipulate toy', 'Social interaction' 'Sit elsewhere', 'Stand elsewhere' and 'Other') were combined as 'Interaction other'. To further reduce the number of variables, combinations of remaining variables were made by grouping behavioural descriptors (i.e. stand, sit, lie down), and separately combining those indicative of dogs' focus of attention (e.g. 'stand with attention on owner', 'sit with attention on owner', 'lie down with attention on owner' combined as 'attention on owner'). These combinations left a total of 15 individual and 5 composite variables, for training by owner and researcher.

A repeated measures GLM was conducted to identify any significant differences in behavioural signs between owner and researcher conducted groups of sub-tests. No differences were found apart from attention on owner and attention on researcher. To conserve differences here, attention on person training the dog was calculated (as mean of attention on owner when owner training, and attention on researcher when researcher was training) as well as mean attention on owner and researcher across both tests. Means of owner and researcher conducted tests were calculated for all remaining variables.

Relationships between composite and individual behavioural variables were explored with a correlation matrix (Spearman rank), and no correlation coefficients >0.6 were identified. No significant correlation was found between the individual behavioural variable 'licking lips' and the composite variable 'tense', despite licking lips being one element of the latter, suggesting that this behaviour also occurred independently of the other signs included in 'tense'. Both variables were therefore retained in further analyses.

After data reduction, behavioural measures for all animals were examined to identify groups of behaviour which commonly co-occurred. Exploratory factor analysis (Principle Components Analysis; PCA) was conducted on all behaviour variables to identify any underlying relationships. An oblique rotation model (Direct Oblimin) was selected as factors were considered unlikely to be entirely independent. An anti-image correlation matrix identified 4 factors with Kaiser-Meyer-Olkin (KMO) Measures of Sampling Adequacy <0.4, which were removed from the model ('stand', 'explore', anticipatory' and 'interaction-other'). Overall KMO was adequate (0.547), and Bartlett's Measure of Sphericity <0.001. Five components were identified with an eigenvalue over 1, and examination of the scree plot supported a 5 factor model.

Development of component associated scales.

Groups of variables suggested by the PCA were combined into scales for comparison between tests. Reliability of grouped variables were calculated as Cronbach alpha; where any variables were substantially (>±0.4) loaded on more than one factor in the PCA, alpha was calculated for all possible combinations of variables and the maximum value obtained was taken to define the scale, which was calculated as the mean of all constituent variables, weighted equally. The score for each animal was calculated for both T1 and T2. Scores were log10 transformed prior to analysis.

Mean salivary cortisol and behaviour scores on each behavioural subscale from T1 and T2 were compared using a mixed between-within measures GLM. To investigate differences between dogs trained with e-collars and positive reinforcement only, a separate model compared the control dogs trained using these methods specifically with their breed age and gender matched animals from the e-collar group. To check for order effects, dogs matched between e-collar, control and extra control groups were compared in a third model. Levene's Test of Equality of Error Variances was non-significant in all cases

Behaviour and Physiology during Standard Task

Results

In total 143 owner-dog dyads were tested in T1. Of these 140 completed at least 2 subtests and were included in development of behaviour factor scores. Sixty three of these were e-collar dogs, 66 controls, and 11 extra controls. In the control group (n=66) 39 owners used training techniques categorized as 'positive reinforcement' and 26 owners used techniques associated with negative reinforcement or positive punishment (terms as defined in Blackwell et al. (2012)). Sufficient salivary cortisol for analysis was collected from 55 e-collar dogs (mean 0.3898µg/dL, SD 0.126), 60 control dogs (mean 0.4500 µg/dL, SD 0.192) and 11 extra controls (mean 0.5687µg/dL, SD 0.399) at T1 and from 56 e-collar dogs (mean 0.4057µg/dL, SD 0.173), 60 control dogs (mean 0.4461 µg/dL, SD 0.194) and 11 extra control dogs (mean 0.5882µg/dL, SD 0.443) at T2.

Under PCA, the structure matrix had five components which explained 67% of the variance in the data (loadings >0.3 shown in Table 10). Variables contributing to Factor 1 suggested dogs which are sitting and paying attention to the trainer, whether this was owner or researcher. Factor 2 suggested dogs which are active and running about during training. Factor 3 combined attention to researcher but not owner, not sitting, but also jumping up, body shaking and paw lifting. Factor 4 described dogs which pay attention to their owner, show ambiguous and not relaxed behaviours, and lick their lips. Attention to owner also loaded on Factor 5, together with composite variables tense and not relaxed. Scales developed from these factors are shown in Table 11.

Interaction effects between group and change between T1 and T2 were found for Behavioural Scale 5 (Wilks' Lambda = 0.968, F=4.219, *P*=0.041), with the e-collar group showing an increase in scores between Test 1 and Test 2 as compared to the control group. Partial eta squared was 0.032, suggesting a small to medium effect size. Between subjects effects were found for Behaviour Scale 1 (F=4.607, P = 0.34, partial eta squared = 0.035) with control dogs scoring significantly higher across both tests. Within subjects effects were found for Behavioural Scale 2 (Wilks' Lambda = 0.841, F=23.862, P<0.001, partial eta squared 0.159), and Behavioural Scale 3 (Wilks' Lambda = 0.970, F=3.940, P=0.049, partial eta squared 0.030) which both decreased significantly from T1 to T2 across all dogs.

When dogs trained with positive reinforcement in the control group were compared with matched dogs from the e-collar group, salivary cortisol increased significantly from T1 to T2 in the e-collar group compared to the control group (N=30 each group, Wilks' Lambda = 0.898, F=6.606, P=0.013, partial eta squared 0.102), as did score on Behaviour Scale 5 (N=36 each group, Wilks' Lambda = 0.939, F=4.059, P=0.048, partial eta squared 0.061). Scores for Behavioural Scale 1 decreased significantly from T1 to T2 in control compared to e-collar dogs (Wilks' Lambda = 0.927, F=5.402, P=0.023, partial eta squared 0.073), although control dogs also showed an overall higher score on this scale across both tests (F=6.366, P=0.014, partial eta squared = 0.014). Scores for Behavioural Scale 2 (Wilks' Lambda = 0.856, F=11.612, P=0.001, partial eta squared 0.144) decreased significantly from T1 to T2 across all dogs.

Comparison between matched dogs in the control, e-collar and extra control groups identified no significant differences between extra controls and controls, nor trends suggesting that adding collars on second tests influenced findings. As with e-collar and control dogs, extra control dogs showed a decrease in scores on Behavioural Scale 2 between T1 and T2, but no other within subjects effects were found.

Table 10: Loadings[1] of behavioural variables from the first set of standard tests (T1) onto five components in Principle Components Analysis[2]

Variable	**Component**				
	1	2	3	4	5
Tense					0.755
Relaxed				-0.303	-0.600
Ambiguous				0.845	
Excited		0.797			
Running		0.835			
Walking		-0.796			
Sitting	0.751		-0.308		
Attention owner	0.542		-0.425	0.339	0.421
Attention researcher	0.676		0.490		
Attention trainer	0.918				
Paw lift			0.721		
Lick lips				0.820	
Body shake			0.457		
Jump up			0.674		

1 only loadings >0.3 shown
[2] using Direct Oblimin rotation with Kaiser normalization

Table 11: Behavioural Scales derived from exploratory Principle Components Analysis

Scale	Variables included
1 ('attentive')	Sit Attention on trainer
2 ('excited')	Excited Run Walk (inverse)
3 ('attention seeking anxious')	Paw lift Jump up
4 ('ambiguous')	Ambiguous Lick lips
5 ('tense attention owner')	Tense Relaxed (inverse) Attention on owner Attention on research (inverse)

Standard Training Tasks
Discussion
This study tested the hypothesis that dogs which had previously perceived the application of a stimulus from e-collars to be aversive would be more likely to show behavioural and physiological signs of stress when tested in a context predictive of further stimulus use, than those which had no prior experience of collar use. This hypothesis relied on a number of assumptions. These need to be taken into account in interpreting the findings of this study,

as they influence the chance that individual dogs show a differential behavioural response when tested with a collar compared to no collar. The assumptions were:

i) That the context in which testing occurred was similar to the context in which the stimulus had previously been applied. Although testing for the standard tests was conducted as closely as possible to the training context in which focal devices had been used, this was not possible in some cases for practical reasons. For example, in a proportion of cases where e-collars had been used to prevent livestock chasing, it was not possible to test dogs close to livestock. This may mean that the specific predictive context for stimulus application was not replicated for a proportion of cases.

ii) That the dog had previously learnt that the context, together with wearing a collar, were predictive cues for stimulus use. It is possible that not all dogs trained with e-collars associated the collar, or even collar and context, with stimulus application. An association will occur where the predictive cues are contingent to the stimulus. However, in some cases, dogs may wear the collar regularly in the training context, but only receive a stimulus rarely. Particularly where the collar was worn on occasions prior to the application of stimulus, the dog may not associate wearing the collar with the stimulus application.

iii) That the use of the device had been recent enough for the association with context to be maintained. In some dogs the focal devices had not been used for some time (e.g. up to a year ago), over which period of time it is possible for associations between contextual cues and stimulus application may have extinguished.

Although control and e-collar groups were matched for criteria such as breed type, the dogs recruited to each group were likely to be variable with respect to a range of other factors which could not be controlled by matching. For example, dogs were not tested for other factors which could influence the likelihood of their developing fear behaviours; lifestyle factors, such as amount of exercise received, diet or previous health; specific learning experiences related to training, such as types of training methods used in the past or specific events which may have influenced responses; nor previous learning experiences related to interaction with owners and unfamiliar people. All of these factors were likely to have influenced the response of individual dogs to an apparently 'standard' training task. In addition, individual owners will have varied in their ability to teach the commands or cues used. Because of this variability, analysis focussed on within-subject comparisons by comparing behavioural and physiological responses between groups both without, and with, a discriminative stimulus associated with the application of stimulus.

Salivary cortisol was highly variable between individual dogs, as has typically been found in other studies utilising dogs of variable background and type (Hiby et al. 2006; Blackwell et al. 2010). However, mean values increased significantly from T1 to T2 in e-collar trained dogs as compared to a matched population of those trained using positive reinforcement techniques. Since only dogs in the e-collar group had previous experience of the collar, differences occurring between tests are postulated to be related to dogs' anticipation of the application of a stimulus when trained whilst wearing an e-collar, and an indication of associated stress in this group. Although cortisol increases with exercise or activity, this is unlikely to explain differences here, since dogs in both groups showed similar changes in activity from T1 to T2. Since cortisol is produced in response to emotional arousal of either valence, consideration of this measure in isolation is difficult to interpret, although concurrent behavioural data suggests a negative association with anticipation of stimulus application.

Dogs in the e-collar group showed an increased score on Behaviour Scale 5 (Tense, not relaxed, attention on owner, not attention on researcher) between T1 and T2, both when compared to all control dogs, and to the sub-set trained with positive reinforcement only. Dogs in this group were more attentive to the owner during the second test, regardless of whether owner or researcher were conducting the training, and in some cases training by the researcher was not possible as dogs would not leave their owner. Since recall problems were a common reason for e-collar use, dogs in the e-collar group may have learnt to not move too far away to avoid stimulus application. Indeed, in studies of e-collars where dogs can learn to avoid the e-stimulus (Dess et al., 1983; Schalke et al., 2007) their acute response to electrical stimuli is moderated compared with application of unpredictable or uncontrollable stimuli. However, the differences found between Test 1 and Test 2 suggests that wearing the collar acts as a discriminative stimulus for this response. An alternative explanation for the e-collar group showing reduced exploration and remaining close to the owner when tested with the dummy collar is that their behaviour was inhibited because of anxiety associated with anticipation of an application of a stimulus. It is well established in literature from other species that anticipated punishment can result in an inhibition of other behaviours within that context (e.g. rodents: Seligman and Meyer 1970, Imada and Okamura 1975; humans: Carver and White 1994). This has been previously suggested as an explanation for the response of dogs to different types of training methods (McGreevy and Boakes 2007). The behavioural response may also be associated with dogs seeking owner proximity in response to anxiety. The close association of the attention change in e-collar dogs with increased duration of the composite postural variable 'tense' and reduced duration of 'relaxed' behaviour, tends to suggest that such behaviour may be indicative of a negative rather than positive valence of emotional state.

Comparison of e-collar and positive reinforcement dogs also suggested a difference between groups in Behavioural Scale 1, sitting attentive to whoever is conducting training. This decreased from T1 to T2 in reward trained dogs as compared to e-collar trained dogs, suggesting a relative increase in focus on trainer when e-collar dogs wore a dummy collar. This is clearly a desired effect of such training, although scores for this measure remained significantly lower than for control dogs across both tests, as discussed below.

Across both tests, dogs in the entire control group (and where positive reinforcement dogs only were used as controls) had higher scores on Behavioural Scale 1 (sitting with attention on whoever was training them). This suggests that dogs which had been trained with methods other than e-collars were more attentive during training. This may reflect differences in the general obedience of dog which led to selection of training methods by owners. However, since these tests are conducted after training with the focal devices, this may also be indicative of different behavioural responses in dogs occurring as a consequence of, or despite, training with different methods. This is compatible with Blackwell et al. (2012), who found that owners who used reward based methods for recall and chasing problems reported higher levels of overall training success.

Dogs in all groups decreased in scores on Behaviour Scale 2 between T1 and T2. This is likely to reflect an overall habituation to the environment, and overall reduced activity over time in the training context. A similar decrease in this scale was identified in the additional control dogs, suggesting that this effect was not related to the order of tests.

Section 3.
Behaviour during collar fitting

Data from 130 dogs (65 control and 65 e-collar) was available for this analysis. A total of 31 states (including their position, posture, activity and apparent direction of attention) and 8 events (including vocalisations, lip-licking and play-bow) were recorded from dogs during collar fitting. In addition, three owner behaviours were recorded: time spent manipulating the collar, duration of not touching the collar and number of commands given to the dog. Time in each state was calculated as a proportion of the total time dogs were in sight, and as rates for events, to account for different time taken for fitting the collar in different dogs. Variables with low frequencies (<10% cases) were removed whilst those with strong negative correlations such as' Dog less than 1m from owner' with 'Dog greater than 1m from owner'; and 'Owner not touching collar' with 'Owner manipulating collar' were reduced to a single variables. Principal component analysis was then conducted on the dog behaviour variables to identify underlying relationships, which produced seven factors that overall explained 54.8% of the variance in the data.

A mixed between-within subjects GLM was conducted to compare the component scores of individual dogs between e-collar and control groups. The analysis did not violate assumptions of sphericity (Mauchly's Test), and Box's Test of Equality of Covariance Matrices and Levene's Test of Equality of Error Variances were non significant, suggesting the analysis did not violate homogeneity and equality of variance assumptions. Factor scores did not significantly vary between dogs in the e-collar and control groups ($F_{1,129}$ =0.276, p=0.6, partial eta squared = 0.002). A wide range of factor scores in both groups of dogs was apparent, suggesting a range of individual behavioural responses in each group.

Of the composite behavioural states, 'tense', 'relaxed', 'ambiguous' and 'anticipatory' were recorded in sufficient cases (>10%) for analysis. The proportion of time dogs showed these behavioural states were compared between e-collar and control groups using a Mann-Whitney U test. No significant differences were found with respect to proportion of time spent in any of these composite variables. However, as with individual behaviours, a wide range of scores were evident for dogs in both groups, suggesting significant individual variation (Figure 9).

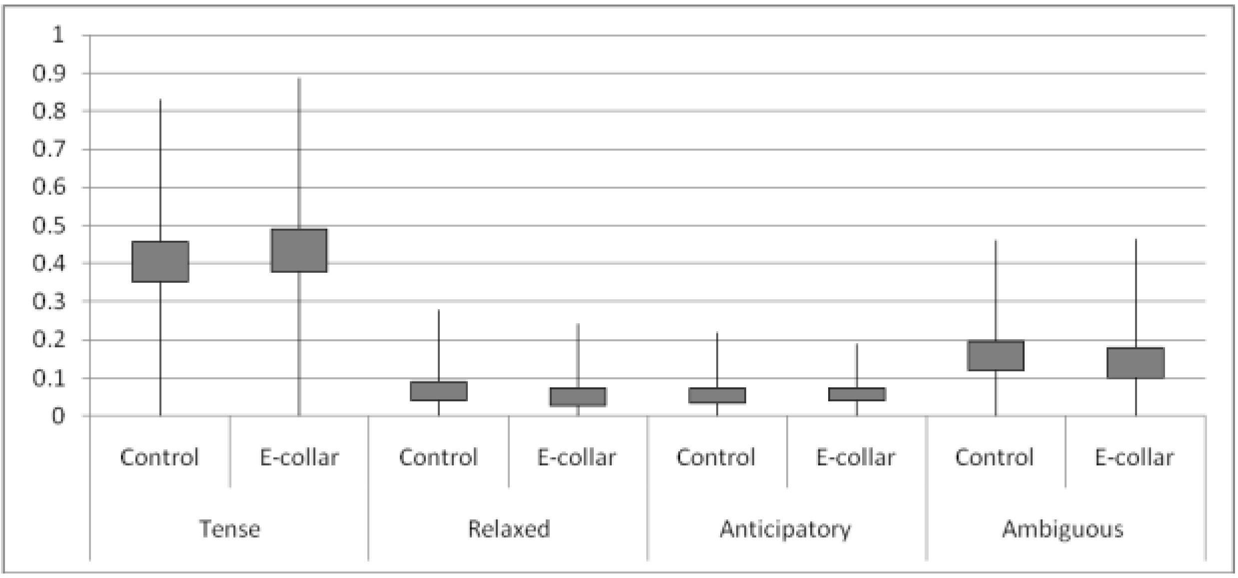


Figure 9: *Graph to show the mean ± standard errors (solid boxes) and standard deviations (lines) of the proportion of time spent tense, relaxed, anticipatory and ambiguous by dogs during collar fitting, divided by group.*

This measure was included in the study as a consequence of researchers observing what appeared to be a severe negative behavioural response to collar fitting in an early case during methodology development, which suggested that recording this event may provide useful insights. In Objective 3, differences between groups were found with dogs in the e-collar group having a higher proportion of time showing behavioural signs which may indicate distress, such as panting.

In the main dataset of Objective 4, the large number of variables collected were reduced using factor analysis, and no overall differences between groups were found with factor scores. However, an important finding in this element of the study was the large variability in individual responses, likely to reflect the learning experiences of individual dogs. Whilst some dogs in both groups showed little response to collar fitting, others showed considerable signs of distress. In the control group, where dogs had no previous experience of collars, this may have been associated with novelty; in the e-collar group such a response to novelty is unlikely given their previous experience, and so it seems reasonable to suggest that this may be due to the fitting of the collar being predictive of a stimulus of some other event. This could also explain why some other dogs in the e-collar group showed excited or anticipatory behaviours, as these dogs may have routinely experienced collar fitting before potentially rewarding events such as going for a walk. Because of the variability in consequences of collar fitting between dogs, together with the variable impact of owner behaviour, the overall findings of this element are difficult to interpret. However, having these descriptive data provide additional qualitative evidence for the study.

Stand alone or baseline physiological measures:

Baseline cortisol values

Urinary cortisol: creatinine was square root transformed, and salivary cortisol log10 transformed prior to analyses. Using a Bonferroni corrected level of significance for multiple comparisons, the baseline cortisol level, as measured in first passage urine, and presented as a ratio with creatinine was not significantly different between the control group (n=57, mean = 1.35, SD 0.17) and the e-collar group (n=56, mean = 1.25, SD = 0.21; t (111) = 2.57, p= 0.026). Similar differences remained when the control group was divided into those trained using positive reinforcement and those trained using other positive punishment/negative reinforcement techniques ((F=3.72, df=2, p=0.028), and post-hoc analysis revealed that dogs in the positive reinforcement group had a higher urinary cortisol:creatinine than dogs in the e-collar group (Mean difference = 0.11, SE= 0.4, p=0.031), although these were also non-significant using a corrected P value.

There was also a difference between groups with respect to the baseline salivary cortisol sample, taken after the arrival of researchers (t = 2.4, df=110, p=0.022), due to dogs in the positively reinforced sub-group having higher cortisol than the e-collar group (e-collar N=55, mean = 3.81, SE 0.15; reinforcement N=34 mean = 4.98, SE = 0.40; punishment N=22, mean = 3.93, SE = 0.27; $F_{2,108} = 6.113$, $p<0.05$), however the effects were not significant once correction was applied.

Neurotransmitter metabolites

No significant differences between dogs in the e-collar group (N = 49, Mean = 1.09, SE = 0.52) and control group (N = 55, Mean = 1.15, SE = 0.51) were found for 5-HIAA concentrations nor for HVA concentrations (both log10 transformed) (e-collar: N = 32, Mean = 1.04, SE = 0.3; control N = 40, Mean = 0.98, SE = 0.42). When the control group was divided between positive reinforcement and punishment/negative reinforcement differences between groups for HVA_log10 there were no differences between groups (F = 2.827, df = 2, p = 0.066; e-collar: N = 32, Mean = 1.04, SE = 0.53; positive reinforcement N = 23, Mean = 0.89, SE = 0.073; positive punishment N = 15, Mean = 1.16, SE = 0.073).

Both the samples of urinary and salivary cortisol taken before the training tasks appeared to be higher in control dogs than e-collar dogs, though application of Bonferroni correction for the multiple separate comparisons made reduced confidence in this effect. Further analysis suggested this may be explained by higher levels in the control dogs which had mainly experienced positive reinforcement training. Because these samples were taken in the morning prior to the training tests, it is not possible to relate these measures to dogs' experiences of training during the standard tests. Owners were asked to collect first morning passage of urine, which would reflect cortisol levels for the overnight period. The baseline salivary cortisol sample was taken after researcher arrival and may have been influenced by dogs' emotional response to this experience, or arousal associated with the dogs daily activity patterns. In terms of circadian rhythms or daily changes in circulating hormones, it is well known that gluco-corticosteroids follow a circadian clock in many species (reviewed by Dickmeis 2009) related to natural patterns of daily activity. Such circadian patterns have been hard to demonstrate in domestic dogs (Johnston and Mather 1979, Koyama et al 2003, Kolevska et al 2003, Castillo et al 2009), or are more closely related to episodic activity rather than a circadian clock (Kemppainen and Sartin 1984, Kolevska et al 2003). In other words in domestic dogs, activity patterns and related daily changes in hormonal concentrations appear to relate to events during the day, rather than follow an internal clock.

Another possible explanation for potential differences in baseline cortisol measures is that the lower level of cortisol recorded as baseline in the e-collar trained dogs was related to hypo-activation of the hypothalamus-pituitary-adrenal axis (Freis et al 2005, Miller et al 2007). E-collar trained dogs, and those largely trained using positive punishment/negative reinforcement may be experiencing dys-regulation of HPA activity resulting in flattening of diurnal patterns of activity and/or blunting of acute responses (see Ruttle et al 2011). However, examination of absolute levels of urinary cortisol: creatinine do not suggest these to be particularly lower than baselines in other samples taken in the home environment (e.g. Rooney et al. 2007), and it is difficult to make any such interpretation based on a single sample.

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Although little difference was identified between measures of urinary neurotransmitter metabolites between groups, their inclusion in this study has led to important methodological developments which will inform further studies. Data will also provide baselines of these variables in the owned dog population for comparisons in future studies. The wide variation in values between individual dogs suggests that very large sample sizes may be required to identify meaningful comparisons with these data.

Cognitive bias task.

Previous studies (e.g. Mendl et al. 2010) used a standard test area size with negative and positive training bowls 4m apart and all bowls placed 3m from the dog's starting position. However in Objective 4 it was not always possible to use a room of suitable dimensions, which resulted in only 37% dogs being tested in a 4X3m arena, 48% in a 3X2m arena and the remainder in arenas of various other dimensions.

Although during recruitment, e-collar and control dogs were matched, a proportion of recruited dogs did not reach criterion on the spatial discrimination task, leaving a number of unmatched cases. To avoid further decrease in sample size all remaining cases were retained and the speed to each probe was scaled to control for potential differences in size between dogs in control and e-collar groups (as described in Mendl et al. 2010). A mixed between subjects GLM was conducted and standardised residuals were found to not be normally distributed. However, square root transformation of scaled speeds resulted in normally distributed residuals. In addition to study group, arena size was included as a between subjects factor. In previous studies, and Objective 3, a standard arena size of 4m x 3m was used, but in this project many dogs were tested on 3m x 2m arenas, (or other dimensions) due to space availability in owners' homes. Other factors which influenced scaled speeds were research group and method of recruitment, as but these strongly correlated with arena size, only the latter was included as a covariate. Because scaled speeds were significantly different where arena sizes other than 4m x 3m and 3m x 2m were used, these cases were removed from the final model. Whether the device had been used in the previous month was also included as a between subjects factor. Normal tests for violation of assumptions for repeated measures GLM were conducted: Mauchly's test of sphericity, Levene's test of equality of error variances and Box's test of equality of covariance matrices were all non-significant.

The scaled speeds to probes for e-collar and control groups were compared. Significant differences in speed to each probe were found (Wilks' Lambda = 0.322, $F_{2,55}$ = 7.979, p<0.001, partial eta squared = 0.678), but no effects of group or interactions were found on speed to probes ($F_{1,56}$ =0.049, p=0.826, partial eta squared = 0.001). However, a significant between subjects effect of arena size was found ($F_{1,56}$ = 5.867, p = 0.019, partial eta squared = 0.095), with dogs tested on the smaller arena size (3m x 2m) having higher scaled speeds to all probes.

Although outside significance at p <0.05, an interaction between scaled speed to probes, training method and test arena size was investigated further because of a reasonable effect size despite small numbers in groups (N = 34 e-collar, 16 positive reinforcement, 14 positive punishment; Wilks' Lambda = 0.871, F (4, 104) = 1.857, p = 0.124, partial eta squared = 0.067). Differences in categories between data collected in standard (4m x 3m) and small (3m x 2m) arena sizes were apparent, which differed between groups. In the standard arena size, dogs in the e-collar group had a slower mean speed to the middle probe, but it is difficult to draw conclusions from this because of small numbers in each category.

The results of the judgement bias task were difficult to interpret because of a number of confounding variables. Of greatest significance was the effect of arena size, and since a significant proportion of dogs were tested using a different arena size, it was impossible to draw any clear conclusions about the effect of group on judgement bias. This is an important finding in informing the methodology in future studies.

Overall project conclusions

Overall, this project has highlighted the very variable outcomes between individual dogs when trained using e-collars. The combination of differences in individual dog's perception of stimuli, different stimulus strength and characteristics from collars of different brands, differences between momentary and continuous stimuli, differences between training advice in manuals, differences in owner understanding of training approaches and how owners use the devices in a range of different circumstances are likely to lead to a wide range of training experiences for pet dogs. Owners reported a number of differences in immediate response to application of training device between e-collars and other devices, including the cessation of on-going activity, but also a relatively high frequency of vocalisations on first and subsequent applications of the e-collar stimuli. Owners of dogs in the e-collar group were more likely to have used the device for recall or chasing problems, and more likely to rate their dog's behaviour as severe, than those in the control population. This may suggest that e-collar dogs may constitute a harder to train sub-population of dogs, though there was no evidence of differences in ease of training or other population differences found in these dogs, from questionnaire or baseline behavioural data, except for a (non-significant) lower baseline level of cortisol in urine and saliva, and a higher proportion of time sitting with attention on the trainer in the control group.

The project did not identify consistent differences in excretion of urinary metabolites and performance in tests of cognitive bias between the two treatment groups, although there were methodological issues confounding findings in the latter. However, for both the data suggest there is considerable overlap between the two populations in these measures and if there were any treatment differences these were small compared with the considerable variation between dogs.

Significant differences were, however, found in data collected from e-collar and control dogs undergoing standard training tests with and without dummy e-collars. These included a difference in the change in salivary cortisol between tests. E-collar dogs showed an increase in this measure in comparison to control dogs trained using largely positive reinforcement approaches. There were also behavioural changes between these two tests that were consistent with changes in emotional state. E-collar dogs showed an increase in a composite behavioural score which incorporated duration of time tense, inverse of duration of time relaxed, and duration of time attentive to owner, whoever was conducting the training, when compared with all controls (and also when just compared with the positive reinforcement sub-population). These training tasks were designed to replicate the context where e-collar training had occurred in the past, and indicate a shift towards higher levels of physiological and behavioural arousal in the e-collar dogs. These findings suggest that the experience of a stimulus is sufficiently aversive in at least a proportion of dogs for them to experience negative emotions when trained in the situation which may predict collar use.

The main conclusions arising from this project are summarised as follows:

1. The impedance of dogs to e-stimulation can be modelled as a passive resistance, which varied considerably both between and within dogs, and was lower for wet than for dry dogs.
2. The 'momentary' function on tested e-collars delivered a sequence of identical short voltage pulses; this sequence, comprising the same short voltage pulses, was longer for the 'continuous' function.
3. There were considerable differences between tested e-collars in voltages and the number of pulses per stimulus
4. The peak voltage varied significantly with the resistance of the dog, but was generated for a few millionths of a second, ensuring that the electrical energy remained constant over a wide range of resistances
5. Stimuli were consistent within tested individual e-collars
6. The developed stimulus strength ranking indicator (SSRI) appears to provide a better measure of relative stimulus strength than dissipated energy.
7. Different e-collar brands varied considerably with respect to energy output and comparative stimulus strength, as well as in the relationships between 'momentary' and 'continuous' stimuli
8. Two faults were encountered, one leading to a lower and one leading to the highest stimulation
9. Manuals generally gave clear advice on collar operation and fit.
10. Advice in manuals regarding the use of e-collars in training was variable and did not always explain the e-collars' full potential for instance on the use of the tone or vibrate function alone
11. Information at the point of sale was generally limited and does not allow meaningful comparisons between e-collars
12. The majority of owners in the study population had used e-collars for specific problem behaviours; recall problems and livestock chasing being most commonly reported.
13. Pilot studies indicated that there may be treatment effects in behavioural and physiological responses to the standard training tasks, but found little other evidence of differences between groups.
14. There was no difference in owner reported perceived success or ease of training between e-collars and other training methods.
15. Owners who had used e-collars and other training methods were equally likely to recommend the training technique to others
16. Owners who had used e-collars were more likely to report preferring to use a different training method in the future than those using other training methods
17. A proportion of e-collars used by owners were acquired second hand, for example via the internet
18. Owners who had used e-collars generally had limited ability to describe how the device should be used in training, and poor recall of how they had actually used it
19. Owners who had used e-collars reported using a range of intensity settings (as expected) with a small proportion (6%) reporting initial use at the highest setting.
20. Over a third of owners reported their dog vocalising on first use of an e-collar, and over a quarter did so regarding subsequent use
21. A large variation in behavioural responses was found between dogs on fitting of collars although no significant differences in behaviour signs were found between groups
22. Cortisol increased in dogs which had previously been trained with e-collars as compared to those trained with positive reinforcement, between testing without a collar and testing with a dummy collar
23. A behavioural scale incorporating proportion of training period tense, an inverse of proportion of training time relaxed, and proportion of time with attention directed at owner (whoever was training) significantly increased in the e-collar group, as compared to both the whole control group and the sub-set of dogs predominantly trained using positive reinforcement.
24. Behavioural scales indicative of activity (excited, running, not walking) decreased from the first to second test, but this did not vary between groups.
25. Individual behavioural signs suggested elsewhere to be indicative of anxiety (licking lips and paw lifting) did not fall in the same components on exploratory factor analysis, suggesting these may not necessarily co-occur in dogs during training. However, scores incorporating these signs did not significantly change between groups across tests.

Glossary of terms used in Final report for Defra Project AW1402

Brand	Denoting a company and/or manufacturer
Capacitance	A measure of the capacity of a component to store electrical charge. Capacitance is measured in units of Farads (F) and is calculated as the ratio of the charged stored (in Coulombs) to the potential difference across the component (measured in Volts).
Contact points	Stainless steel probes protruding out of the receiver which make contact with the dog's neck and transfer the stimulus.
Continuous stimulus	An electrical stimulus which lasts for as long as the button is pressed. As in most e-collar models this was time-limited until the button was re-depressed, this is written in quotation marks throughout the document, indicating it is close to, but not always entirely continuous.
Dummy collar	A collar and imitation receiver unit with similar physical attributes (weight and size) to an e-collar receiver but without any functionality.
ECMA	Electronic Collar Manufacturers Association
E-collar	Used here to refer to training collars that emit an electrical stimulus controlled via a remote hand-held device. Other types of electronic collars such as the so called 'anti-bark' collars, or collars that use a (citronella) spray were outside the remit and have not been considered, neither were e-collars that are part of a pet containment system. Where e-collar is used this refers to both the handset and receiver.
Handset	Refers to the part of the e-collar that is held by the user, encompassing stimulation buttons and level settings.
Impedance	Describes the opposition to the flow of electrical current within a component. The term extends the concept of resistance because it describes not only the relative amplitudes of the voltage and the current, but also their relative phases which are determined by the capacitance or inductance of the component.
Level	Referring to the intensity setting on the e-collar
Model	Specific design of e-collar within a brand
Momentary stimulus	Short electrical stimulus lasting between 4 and 500mS.
Negative reinforcement	Where the probability of a behaviour occurring in the future is increased when the behaviour is followed by the removal or avoidance of a negative stimulus.
PAC	US based e-collar manufacturer. Not a member of ECMA.
Positive punishment	Where the probability of a behaviour occurring in the future is decreased when the behaviour is followed by an aversive event.
Positive reinforcement	Where the probability of a behaviour occurring in the future is increased when the behaviour is followed by the application of a positive stimulus.
Pulse	Single transient wave in the normal electrical state (a 'momentary' stimulus administered by an e-collar can consist of one of more pulses).
Receiver	Refers to the part of the e-collar that is around the dog's neck and emits the electrical stimuli.
Resistance	A measure of the opposition to the flow of electrical current in a component. Resistance is measured in units of Ohms (Ω) and is calculated as the ratio of the potential difference required to generate a current (measured in volts) to the resulting current (measured in Amps).
Stimulus or stimuli	Neutral term that refers to the electrical impulse or 'shock'.
Tone	Referring to the sound function on the receiver which can be controlled from the handset of the e-collar.
Vibration	Referring to the rapid small movement function on the receiver, controlled from the handset of the e-collar.

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

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