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Repetitive behaviour in kennelled domestic dog: Stereotypical or not?

Hamish D.C. Denham [a,b,1], John W.S. Bradshaw [c], Nicola J. Rooney [c,*]

[a] Royal (Dick) School of Veterinary Studies, The University of Edinburgh, Easter Bush Veterinary Centre, Roslin, EH25 9RG, United Kingdom
[b] Royal Army Veterinary Corps, Royal Army Medical Directorate, Army Headquarters, Former Army Staff College, Slim Road, Camberley, Surrey GU15 4NP, United Kingdom
[c] Anthrozoology Institute, Animal Welfare and Behaviour Group, University of Bristol, School of Veterinary Sciences, Langford BS40 5DU, United Kingdom

HIGHLIGHTS

- The majority of 30 kennelled dogs showed repetitive behaviour when stimulated.
- These dogs could be divided into four groups, based on their repetitive behaviour.
- There were significant differences between groups in their response to a stressor.
- Dogs which behaved repetitively when unstimulated responded atypically to stress.
- Connections between repetitive behaviour and wellbeing in dogs need further study.

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ABSTRACT

Repetitive behaviour is common in kennelled dogs, yet its motivational basis remains relatively unexplored. We examine the repetitive behaviour of 30 kennelled working dogs in ten contexts both coinciding with, and in the absence of, commonly occurring arousing stimuli, such as care staff, other dogs and food preparation. A large proportion (93%) of subjects performed some repetitive behaviour, most commonly bouncing, but only 17% in the absence of the arousing stimuli. Subjects could be divided into four groups according to the stimuli eliciting, and the duration, of their repetitive behaviour, and these groups were compared on the basis of their cortisol response to an acute psychogenic stressor — a veterinary examination. Urinary cortisol/creatinine response curves differed significantly between the groups. In particular, those dogs which performed repetitive behaviour at times of minimal stimulation, showed a distinctly different pattern of response, with cortisol levels decreasing, as compared to increasing, after the veterinary examination. We conclude that dogs showing repetitive behaviours at times of high arousal are motivationally distinct from those "stereotyping" in the absence of stimulation. We suggest that those dogs showing spontaneous repetitive behaviours may have past experiences and/or temperaments that affect both their reactions to a veterinary examination and to long-term kennelling. For example, some dogs may find isolation from humans particularly aversive, hence affecting their reactions both to being left in a kennel and to being taken to the veterinary surgeon. Alternatively, such dogs may have atypical responsiveness of their hypothalamic–pituitary–adrenal (HPA) axis, possibly brought about through chronic stress. High levels of repetitive behaviours in response to inaccessible husbandry events may be explained if such behaviour has inadvertently been reinforced by attention from staff, and therefore may not always be indicative of aversion to kennelling or compromised welfare.

1. Introduction

Repetitive and invariant behaviour patterns, with no obvious function or goal, are often defined as stereotypical [1]. At the population level, such behaviours are commonly thought to indicate poor welfare, since they develop in situations where an animal may be frustrated, stressed, fearful, restrained or lacking stimulation and higher incidence is usually seen in environments where other indicators of poor welfare co-occur [1]. However, at an individual level, within a given environment, stereotypies often occur in individuals which are "better off" and show fewer concurrent symptoms of poor welfare than their non-stereotyping counterparts, as their performance may help animals to cope [2]. Therefore the use of stereotypical behaviour as an indicator of welfare, needs to be interpreted with caution, as whilst the presence of such behaviour in a given environment is cause for concern, those individuals showing the highest levels, are not necessarily those suffering the most.

* Corresponding author at: Anthrozoology Institute, University of Bristol, School of Veterinary Sciences, Langford BS40 5DU, United Kingdom. Tel.: +44 117 928 9469, +44 781 841 3310 (mobile); fax: +44 117 928 9582.
E-mail addresses: hdcdenham@hotmail.com (H.D.C. Denham), Nicola.Rooney@bristol.ac.uk (N.J. Rooney).
[1] Current address: Alan Jeans Veterinary Services Ltd., The Surgery Wesley Road, Girvan, Ayrshire KA26 9DB, United Kingdom. Tel.: +44 1465 714418.

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Studies of stereotypic behaviour in captive farm, laboratory, and zoo animals have increased dramatically in recent years [3], and have started to methodologically investigate causation as well as form. However, large numbers of companion animals, and in particular dogs, are kept in confinement, and very commonly exhibit repetitive behaviours; up to 46% of kennelled dogs have been observed to exhibit repetitive behaviours [4] on average for over 30% of the observed time [5]. However, systematic study of the causes of repetitive behaviour in this species is currently sparse.

A number of authors have interpreted repetitive behaviour in kennelled dog as indicative of compromised welfare [6–9], and chronic stress [10,11]. Behaviours described include repetitive pacing (walking or trotting back and forth along a boundary line), circling (walking or trotting around pen), spinning (turning in a tight circle pivoting about hind legs), and wall bouncing (jumping at wall and rebounding); [12]; all of which have been observed in dogs kept in restricted environments e.g. rescue shelters [7] and laboratories [13]. However, levels reported vary substantially. This is unsurprising given the range of methodologies used and that dog behaviour has previously been shown to differ according to time of day and presence of an observer [14]. One of the defining features of stereotypical behaviours in general is that the behaviour is not only repetitive but also apparently functionless. However, deciding whether a behaviour has a function is often problematic. Therefore, Mason suggests a better distinction may be, between "abnormal repetitive behaviours" and "stereotypical behaviours" the latter of which can be demonstrated to be caused by deficits in housing that induce frustration, whilst causality of the former may be unknown [15]. We question whether every dog observed to perform repetitive behaviours can really be described as stereotypical, and hence whether all these behaviours are indicative of compromised welfare.

Several case studies have described the development and treatment of reportedly stereotypical behaviour in pet dogs [16,17]. Drugs trials using open field tests often report increased stereotypical behaviour, for example in response to L-deprenyl (a treatment for Cushing's disease and senile mental deterioration) [18] and adrafinil (a vigilance enhancing drug); [19] and concurrent with cognitive decline [20]. Population-based analyses investigating why some dogs develop repetitive behaviours, whilst others do not, are rare. It is widely believed that specific repetitive behaviours are more common in certain breeds [17] for example tail-chasing in German Shepherd Dogs [21]. Detailed owner surveys found a reduced prevalence of repetitive tail chasing behaviour to be linked to nutrient supplementation (specifically B6), later maternal separation, neutering, multi-dog households, and the presence of children, but levels did not vary between four breeds (deliberately selected for apparent tail-chasing proneness [22]).

Similar aetiological studies for other repetitive behaviours are currently lacking, and the form and motivation behind repetitive behaviours in kennelled dogs are far from understood. Therefore we systematically studied repetitive behaviours in a population of kennelled working dogs. We recorded behaviour both during periods of high arousal promoted by the presentation of external stimuli, and periods of low arousal, free from human contact and under minimal external stimuli. In the former, we presented stimuli regularly encountered in a kennel environment, such as food delivery and other dogs passing by, known to be particularly arousing. We hypothesised that these would elicit the performance of repetitive behaviour in a majority of dogs, and that the number and type of situations in which dogs performed repetitive behaviour would differ with their motivation and potentially also their welfare status.

We then compared groups of individuals responding in different ways using a physiological indicator of stress, urinary cortisol/creatinine ratio (C/C ratio). C/C ratio is a useful measure of acute stress in kennelled dogs [23,24] with excretion products in urine pooling over several hours [25]. However during chronic stress, absolute levels have given conflicting information and may be unreliable [26,27,9,28]. More reliable information may be obtained by challenging the HPA system and measuring its responsiveness, changes being potential evidence of chronic stress [28]. Whilst studies often suggest that chronically stressed animals become hyper-responsive [28] past studies of children [29] and detailed studies of beagle dogs indicate that chronically stressed animals can be hypo-responsive (e.g. [30]). Challenging the system can be done by administration of secretagogues such as CRH and ACTH (e.g. [30]) or via non-invasive behavioural means. For example, Horváth et al. [31] used a challenge involving an unfamiliar human approaching threateningly, to elicit an HPA response in working police dogs. Here we use a commonly aversive stimulus, a clinical veterinary examination which has been demonstrated to act as an acute stressor for many dogs [32]. We applied this standardised stressor to the thirty dogs and measured their urinary cortisol levels before and at three points post-application, using the same methodology as Gaines [12] based on that validated by van Vonderen et al. [32]. We then compared the physiological responses of the dogs with their repetitive behavioural profiles, to explore potential differences in welfare status.

2. Materials and methods

2.1. Subjects

The subjects comprised thirty male German Shepherd fully trained Police Dogs, six of which were neutered; ages ranged from 18 to 112 months (mean = 4 years 2 months ± 2.2 years). The dogs had diverse and unknown original backgrounds, with most procured as young adults by the working dog training establishment (therefore, for the older dogs, time living in kennels could not be estimated accurately, but would presumably have correlated strongly with age). To be included in the study, they must have been resident in their current dog section for more than three months and not be on any prescription medications; dogs receiving dietary supplements (fatty acid, Omegas 3 and 6 or pancreatic enzymes) were included.

2.2. Housing and husbandry

The study took place at a working dog establishment in the UK which had accommodation for forty working dogs in individual wooden kennels each comprising a loose run area (4.8 m^2) and an enclosed resting area (1.4 m^2). The kennels were arranged in two rows facing each other with a central access aisle and access passages at each end and half way up the rows. The whole kennel area was without external walls, but was covered by a metal framed curved roof which also covered adjacent feed preparation and animal treatment rooms. The sound of food preparation, which could be heard throughout the kennels, was used as one of the experimental stimuli, but these areas were not accessed at any other time during the experiment. Three larger loose run compounds were located outside (each including a sheltered area) to provide the dogs with a space for exercise out of their kennels.

Table 1
Schedule of data recording.

Day 1	0700 − ±30 min	Urine sample 1
	1000 − ±30 min	Clinical examination
	1015 − ±30 min (immediately after examination)	Urine sample 2
Possible time of stimulus presentation		
	1215 − ±30 min (2 h after exam)	Urine sample 3
	1245 − ±15 min	Minimal stimulation recording 1
Alternative time of stimulus presentation		
	1700 − ±30 min	Minimal stimulation recording 2
Day 2	0700 − ±30 min	Urine sample 4

The dogs were fed twice daily at 0630 and 1600 when on duty, or 0630 and 1230 if resting. Following morning feeding each day, the care assistants cleaned each kennel whilst rotating dogs through the loose run compounds. The cleaning routine was completed by 1000 h. Between 1000 and 1630, all resting dogs were given two 15 minute walks by the care assistants. Dogs which were on duty, worked for 12 h and were exercised and fed by their own handler. The duty cycle was either 0630–1830 or 1830–0630 in a 28 day cycle, with each dog working seven nights and seven days interspersed by fourteen rest days in blocks of two or three days. To standardise exercise levels (which may affect cortisol), all testing was conducted on a single day (the second rest day within a duty cycle), ensuring that the dogs had also been resting the previous day. On the testing day, the subjects underwent the following procedures in the same order; urine sampling, a veterinary examination and behavioural recording (Table 1).

2.2.1. Urine sampling and veterinary examination

Four naturally voided urine samples were collected (using a plastic tray) from each subject, one prior to, and three following, a standardised veterinary examination. The first urine sample was collected between 0630 and 0730 in an attempt to obtain the first naturally voided sample of the day. Between 0930 and 1030 each dog was subjected to a clinical examination. This commenced with an assessment of the animal's gait outdoors on a flat tarmac surface. A leather muzzle was then applied by a handler or care assistant, and the subject walked into the feed preparation area, and weighed on an electronic platform scale. The dog was then led into the treatment room, where a veterinary surgeon (male, 32 years) conducted an examination including inspection of the eyes, ears and teeth, penis, prepuce and testicles (when present), and palpation of the parotid salivary glands, and sub-mandibular, prescapular and popliteal lymph nodes. Movement of all joints in the fore and hind limbs, was followed by inspection of the feet, pads and nails, skin and coat, assessment of body condition, and abdominal and spinal palpation. It concluded with auscultation of the heart and lungs and taking the rectal temperature using a digital thermometer.

The dog's regular handler or a familiar member of the care staff was present throughout and also collected all urine samples. A second urine sample was collected immediately after the veterinary examination, followed by a third sample 2 h later. The final sample was collected the following morning between 0630 and 0730. Voided urine was collected in plastic containers and immediately transferred into plain plastic vials and refrigerated. Batches of samples were sent on the day of collection by next day delivery service to NationWide Laboratories Ltd., (Poulton Le Fylde, Lancashire) for analysis of cortisol by radioimmunoassay (un-extracted) and creatinine by spectro-photometry following reaction with sodium hydroxide and picric acid. Cortisol: creatinine (C/C, measured in nmol/l:nmol/l $\times 10^{-6}$) ratios were then calculated.

Table 2
Stimuli presented to the dogs.

Stimulus name	Description
Care assistant kennel	One of two familiar care assistants stood in front of the subject's kennel clicking the clip on the end of a leash (an action commonly used as an auditory cue ahead of dogs being taken for a walk) for 30 s.
Care assistant walkpast	The same care assistant walked through the kennel complex again clicking a clip on the end of leash.
Dog & care assistant walkpast1	The care assistant walked one of two familiar non-aggressive male dogs up the central passage past the subject.
Dog & care assistant walkpast2	As per above, but walking in the opposite direction.
Feeding preparation	The care assistant produced noises regularly made during preparation of lunchtime feeds e.g. food being measured into food bowls.
Feeding delivery	The care assistant placed a bowl, containing feed, outside the subject's kennel for 1 min, before opening the kennel door and placing the bowl inside.
Stranger kennel	A male person unfamiliar to the she subjects stood outside the kennel for 30 s.
Stranger walkpast	The same stranger walked through the kennel complex.

2.2.2. Behavioural recording

Each subject was presented with a standardised set of eight stimuli (Table 2) which preliminary experiments had suggested increased general arousal levels. These were presented between 1000 and 1530, with a minimum of 1 min since the previous stimuli. Only the experimenter and those persons integral to the stimuli were present. Other disruption was kept to a minimum. Video recordings of the dogs' behaviour were taken before (to allow habituation to the camera), during, and after presentation of each stimulus. Behaviour was also recorded during two periods of minimal stimulation when no humans were present in the kennel block i.e. 30 min 1230–1300 (midday) and 1 h 1630–1730 (evening i.e. after the care assistants left but before evening handlers arrived). Subjects were studied in groups of four between May and July. Stimuli were presented in the same order and at the same time to all dogs. Due to restrictions on the direction of travel through the kennels, it was impossible to randomise the order in which individual dogs were presented with the stimuli, thus dogs were always exposed in the same order.

From each of the video recordings, 1 min of continuous behavioural observation was made from the start of the presentation of the stimulus. We recorded the presence and form of any repetitive behaviour defined as a dog performing at least two consecutive:

- bounces — jumping at a wall and rebounding from it or jumping on the spot either all four legs leaving the floor or hind legs continuously in contact with floor and forelegs only leaving the floor;
- spins — turning in a tight circle pivoting about hind legs;
- circles — walking or trotting around perimeter of pen;
- paces — walking or trotting back and forth along a boundary or imaginary line; or
- any combination of the above.

For the recordings made during times of minimal stimulation, five-minute samples were selected at random and the same measures were taken.

The duration of all repetitive behaviours was also graded, on a scale of 0–3:

0 = no incidence of repetitive behaviour during observation time;

1 = <50% of observation time exhibiting repetitive behaviour;
2 = >50% but <100% of sample time exhibiting repetitive behaviour;
3 = 100% of observation time involved in repetitive behaviour.

2.2.3. Data analysis

All data was analysed using SPSS version 17 (IBM: Guildford, UK). Grades of response were not normally distributed so were analysed using non-parametric tests. Patterns of correlation between stimuli were explored using Spearman's rank correlations and Principal Components Analysis with varimax rotation was used to determine four groupings of dogs. Form and stimuli were compared using McNemar tests, Fisher's Exact tests, Kruskal–Wallis and Mann–Whitney U tests, and inspection of residuals. Cortisol/creatinine (C/C) ratio data were Log_{10} transformed to achieve a normal distribution. Repeated measures ANOVA was used to compare C/C across the four samples and between the four groups of dogs, as defined by repetitive behaviour profile, with age and neuter status of dog included as factors.

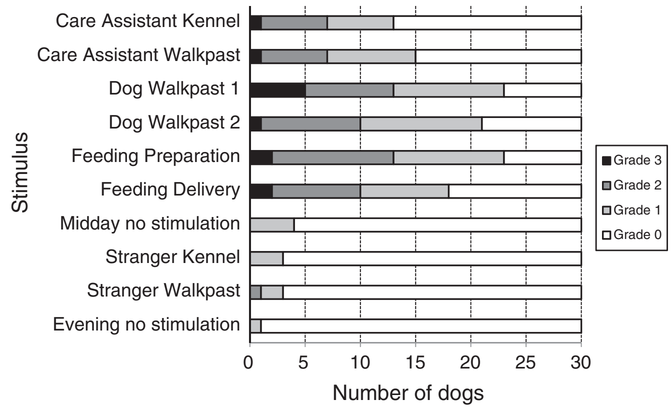

Fig. 1. Numbers of dogs performing repetitive behaviour at each of the three grades of response (see above) to each of the eight stimuli presented, and during the two periods of Minimal Stimulation. Stimuli are listed in the order in which they were presented.

3. Results

Overall, repetitive behaviour was observed in 41.3% of samples taken (out of 30 dogs, 10 samples each). Only two dogs were never observed to perform repetitive behaviour.

3.1. Stimuli eliciting repetitive behaviour

The number of dogs that responded at all, and the grade of their repetitive behaviour, varied considerably between each of the ten stimuli (Fig. 1). The majority of dogs performed repetitive behaviour when presented with the four consecutive stimuli beginning with the care assistant walking a dog past the kennel. Only a few dogs performed repetitive behaviour to the remaining stimuli, including the unfamiliar person, who induced significantly less repetitive behaviour than did the care assistant (McNemar test, Kennel situation, Walkpast situation both $P = 0.02$). Very few (5) performed any repetitive behaviour during the two recordings when no stimuli were presented, and none for more than half the sample period (i.e. grades 2 and above).

Grades of response were significantly positively correlated (Spearman rho > 0.36, $P < 0.05$) between 15 of the possible 45 pair-wise combinations of stimuli, indicating that responses were not all independent. Principal Components Analysis followed by varimax rotation indicated considerable overlap in response between the five consecutive stimuli Care Assistant Walkpast to Feeding Delivery (Table 2), accounting for nine of the significant correlations; and separately, overlap between Care Assistant Kennel and Stranger Kennel (rho = 0.437, $P = 0.02$). The three remaining stimuli, Stranger Walkpast and Midday and Evening No Stimulation, elicited little repetitive behaviour, and in different dogs. These stimuli were combined according to their nature: Stranger Walkpast was deemed most similar to Stranger Kennel, because in both cases the stimulus was an unfamiliar human, and Evening No Stimulation was identical to Midday No Stimulation apart from the time of day. Accordingly, grades were averaged in three groups prior to further analysis: the sequence Care Assistant Walkpast to Feeding Delivery was combined into "Husbandry Events," Care Assistant Kennel, Stranger Kennel and Stranger Walkpast as "Person Presence", and Midday No Stimulation and Evening No Stimulation as "Minimal Stimulation".

Taking these three categories of stimuli and representing them graphically, several distinct patterns of response were evident that allowed individual dogs to be categorised according to the grade of their response and the types of stimuli to which they responded (Fig. 2). In addition to the two dogs that did not display any repetitive behaviour, a further ten only performed it during Husbandry Events, at an average of less than 50% of the sample time (low response group, $N = 12$: Fig. 2a, lower left cluster). Five dogs also only performed during Husbandry Events, but for an average of more than 50% of the sample time (intense response group, $N = 5$: Fig. 2a, lower right cluster). Eight dogs performed repetitive behaviour only when a person was present (i.e. during Husbandry Events *and* Person Presence but never during Minimal Stimulation; response to person group, $N = 8$: Fig. 2a, centre to upper right cluster). Five dogs performed repetitive behaviour to one or other of the two Minimal Stimulation periods, of which four also performed at high intensity to most stimuli (response to minimal stimulation group, $N = 5$: Fig. 2b). The most extreme of these performed repetitive behaviour for more than half of the Minimal Stimulation sample time, and in response to nine out of the ten stimuli. The four groups did not differ significantly in age (Kruskal–Wallis Chi-square = 6.34, $P = 0.10$) or in neuter status (Fisher's Exact Test, $P = 0.20$).

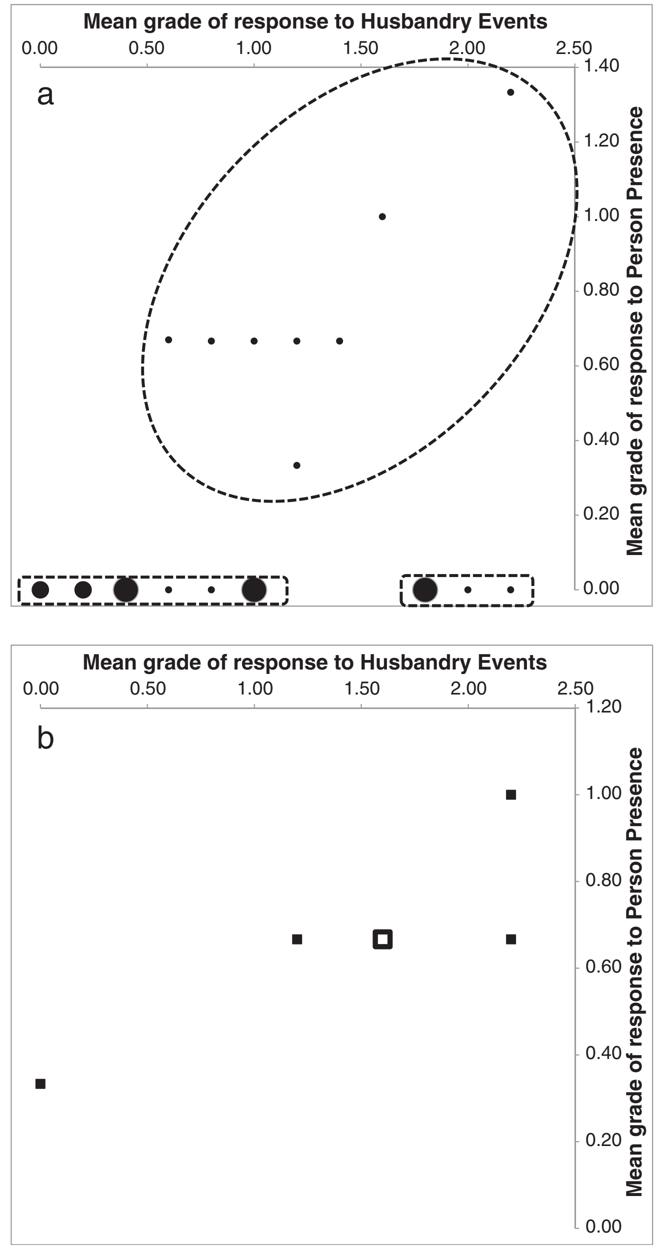

Fig. 2. a. Average grade of response to two combinations of stimuli; Husbandry Events and Person Presence (see text), for 25 dogs that showed no repetitive behaviour to the two periods of Minimum stimulation. Size of points indicates number of dogs with the same pair of values: small circles, one dog; medium circles, two dogs; large circles, 3 dogs. b. Average grade of response to two combinations of stimuli, Husbandry Events and Person Presence (see text) for the five dogs that showed repetitive behaviour during one of the periods defined as Minimal Stimulation. Solid squares: repetitive behaviour during daytime Minimal Stimulation; open square: repetitive behaviour during night-time Minimal Stimulation.

3.2. Form of repetitive behaviour

Apart from the two dogs that never performed repetitive behaviour, and one dog which only performed Circle, all others performed more than one form (two forms, 13 dogs; three forms 13 dogs; one dog performed Spin, Bounce, Pace and Circle). Pace was never performed on its own, only in combination with other repetitive behaviours. Bouncing was the most common repetitive behaviour recorded, occurring as the only behaviour in 16 samples (categorised as Bounce), and in combination with Pace in a further ten (categorised as Bounce/Pace), with Spin in 39 and with Circle in two; the latter were combined for subsequent analysis as Bounce/Rotate. Spin was recorded in an additional 23 samples, and Circle in 19. Three or more forms were recorded in 15 samples. Each sample was thus assigned to one of the following categories: Spin (only), Bounce (only), Circle (only), Bounce/Pace, Bounce/Rotate, and Multiple (three or more forms alternating or in combination).

Dogs which often performed Spin were rather unlikely to perform Multiple repetitive behaviours (rho = −0.42, P = 0.03), and those that performed Circle were rather unlikely to perform Bounce/Pace (rho = −0.40, P = 0.04), but otherwise there were no associations between different forms of behaviour at the level of the individual dog.

The mean grade for Circle was 1.21, significantly lower than the average grades for the other categories of form, for which the average grade was 1.66 (all 6 categories, Kruskal–Wallis $\chi^2 = 11.05$, df = 5, P = 0.04: Circle omitted, K–W $\chi^2 = 3.78$, df = 4, P = 0.44). The number of forms that a dog performed was positively correlated with the average grade of their repetitive behaviour (rho = 0.38, P = 0.047), i.e. dogs performing a longer duration of repetitive behaviour also exhibited more forms. Neither the number of forms nor the average grade was related to age (Spearman rho = 0.23, 0.05; P = 0.22, 0.79 respectively) or to neuter status (Mann–Whitney U = 54, 47; P = 0.32, 0.19 respectively).

The types of repetitive behaviour were unevenly associated with the ten experimental situations t (Fisher's Exact Test = 73.0, P < 0.001); the distribution of the standardised residuals indicated that this was largely due to Bounce/Rotate being associated with the two Dog and Care Assistant Walkpast stimuli. By contrast, only one of these dogs, and no other, performed Bounce/Rotate during the next consecutive stimulus (Feeding Preparation) although the number of dogs performing any kind of repetitive behaviour was both high and similar in these three situations (Fig. 1). It is therefore possible that bouncing combined with rotational behaviour indicates a higher degree of arousal than other repetitive behaviours. With this exception, the form of the repetitive behaviour did not seem to be interpretable in terms of its motivation. Therefore we compared the physiological measures only with the response groupings based on stimuli and intensity not their form.

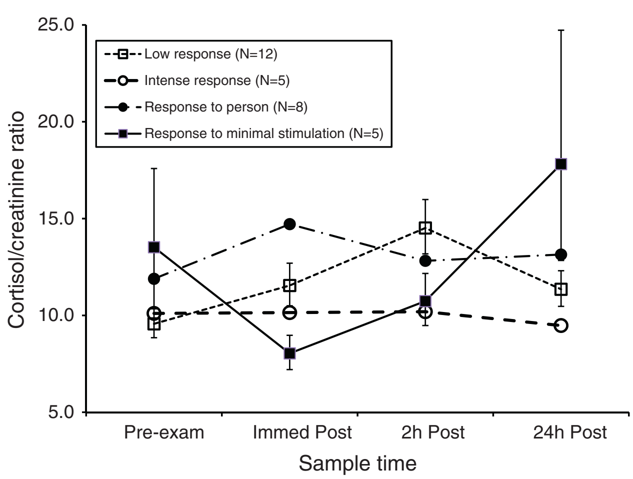

Fig. 3. Mean urinary cortisol:creatinine (C/C) ratios ($\times 10^{-6}$) and SEM for the four groups of dogs, based on their behavioural responses to the experimental stimuli, plotted against the time the urine sample was taken. Urine samples were taken approximately 2 h before and immediately after a veterinary examination, 2 h after, and on the next day. Standard errors are back-transformed from $\log_{10}$-transformed values, and for clarity are only shown for the two most extreme groups.

3.3. C/C ratios

Mean urinary cortisol:creatinine (C/C) ratios for individual dogs ranged from 6.5 to 19.3 × 10^{-6} nmol/l, mean 11.8 × 10^{-6} nmol/l. Average C/C ratios differed significantly between the four urine sample times (Friedman Chi^2 = 9.12, df = 3, P = 0.03); the day 2 and the day 1, 2-hour post-examination ratios were significantly higher than the day 1 pre-examination levels (Wilcoxon tests: Z = 2.52, P = 0.2; Z = 2.047, P = 0.04 respectively).

At the first (pre-examination) sample, the four groups defined by the stimuli responded to (as shown in Fig. 2) were similar ($F_{3,26} = 1.38$, P = 0.27). However, the pattern of change in C/C over the four urine sample times differed between these four groupings (repeated measures ANOVA; within-subjects $F_{9,75} = 2.55$, P = 0.01). For the five dogs showing repetitive behaviour during Minimal Stimulation (Minimal Stimulation group), C/C was lower in the two post-examination samples on day 1 than in the pre-examination urine sample, in contrast to the increase post-examination in the other three groups (Fig. 3). The other three groups were not significantly different from one another in their patterns of response (repeated measures ANOVA; within-subjects $F_{6,63} = 1.30$, P = 0.27). Neither the age (F = 0.85, P = 0.36) nor neuter status of the dog (F = 1.58, P = 0.22), significantly affected the C/C ratio.

4. Discussion

This study has confirmed that kennelled dogs commonly exhibit repetitive behaviours when presented with an array of stimuli, however individual dogs differ in the stimuli to which they respond. When observed in ten scenarios, an unexpected 28 out of 30 of the dogs showed repetitive behaviours (RB) at least once. If this were simply reported as 93% of animals, it could appear to indicate a widespread welfare decrement. However the detailed methodology used in this study suggests that this may not be an accurate interpretation.

The stimuli had differential power to elicit repetitive behaviour, with a dog walking past (with accompanying person) causing most dogs to show RB for over 50% of the 1 min of observed time, and food preparation resulting in the most individuals showing any RB. However, none of the dogs responded to all ten scenarios and only five performed repetitive behaviours under minimal stimulation. Most dogs responded "repetitively" only during husbandry events. These dogs would be unlikely to have been recorded as exhibiting RB in past studies, unless their behaviour was recorded by the care assistant during husbandry procedures. This explains the large discrepancies between care staff-reported and researcher-generated behavioural data (e.g. Gaines [12]). Previous studies have predominantly used remote video recordings (i.e. minimal stimulation e.g. [24]), or an observer (usually a stranger, e.g. [14]) standing outside the kennel, which we can now suggest would detect repetitive behaviour in only a proportion of the dogs which actually display such behaviour. Hence the overall proportion exhibiting repetitive behaviour in this study exceeds all past reports (e.g. [6,23]). This highlights the importance of standardising the context and surrounding stimuli when comparing the prevalence of repetitive behaviour between studies, and environments, and of making observations in the presence as well as the absence of stimuli. It also raises the question as to whether all the different types of repetitive behaviours, under all contexts examined, can be described as "stereotypical", and which, using the definition posed in the introduction, show evidence for inadequate housing, or compromised welfare.

The repetitive behaviour took several distinct forms, and individual dogs appeared to show very distinctive and individual patterns, possibly resulting, at least in part, from their diversity of backgrounds and previous living environments. We note that pacing was never observed alone (without another form) in response to any of the stimuli, which differs from other captive Carnivora, amongst which cage-pacing is common [33]. This may be a result of the small width of kennels relative to the dog's length making it difficult to pace boundaries, and the relatively high levels of stimulation outside the kennel. Spinning and bouncing were very common and often occurred in combination. Overall there was great variability in the contexts under which individual dogs responded, and the form and duration of the repetitive behaviours they showed. Nevertheless, the thirty dogs could be divided into four meaningful and distinct groups, on the basis of their behavioural responses, which also differed significantly in terms of their cortisol response to a (presumed) psychogenic stressor.

The majority of dogs responded "repetitively" only to husbandry events (or not at all), most commonly for less than half the observed time (low response, 12 dogs) or for more than half the time (high intense response, 5 dogs). Eight "response to person", dogs showed RB not only during husbandry events but also when either the care assistant or a stranger stood outside or walked past their kennel. The final 17% also performed repetitive behaviours during periods of minimal stimulation. Not only are the scenarios to which this final group respond intrinsically different, but importantly, the dogs' physiological profiles in response to the veterinary examination distinguish them from the remainder of the population.

The behavioural profile groups did not differ in their baseline cortisol levels, and the general pattern of change in C/C in the population was as predicted and as reported previously [32]; mean levels increased 2 h after, and remained high the morning after, the application of the stressor. Hence, in this population, as Haverbeke et al. [5] concluded for Belgian military dogs encountering novel stimuli (e.g. model cars), most individuals were still responding physiologically to environmental challenges, and hence had a functioning HPA system, even after many years in kennelling, which is often presumed to be a chronic stressor.

However the pattern of change in C/C did vary significantly between the groups. The "low responders" and "response to person" groups showed similar-shaped traces, with noticeable peaks in C/C post application of the stressor as seen in past studies [32], although the timing of those peaks varied, perhaps corresponding to differences in the part of the procedure (e.g. removal from the kennel) which the dogs in each group found the most arousing or stressful. The "intense response" group, although not significantly different from the remainder of the population, appeared to show a dampened increase in C/C, which may be suggestive of some decrease in HPA responsiveness; similar to the hypo-responsiveness that has been reported in previous studies of kennelled dogs [30]. However, most atypical were the five dogs which engaged in spontaneous repetitive behaviour under minimal stimulation, and showed significantly different C/C profiles. They had an inverse trace, compared to the other three groups and to many past results in pet populations [32], showing a decrease in C/C following the challenge. The stressor was psychogenically complex, involving removal from the kennel environment by a familiar human to whom the dog was likely attached, followed by muzzling, restraint and examination by an unfamiliar human, and hence several explanations for his result are plausible.

It may be that dogs in this group had altered HPA functioning (potentially due to chronic stress), as compared to the remainder of the population, which ACTH challenge tests might help elucidate. Alternatively, their past history (e.g. whether they had been gradually habituated to veterinary surgeries) or aspects of their personality, may have led to a difference in the way these dogs perceived the challenge: they may not have experienced the veterinary examination as a stressor, but actually found it calming or even rewarding, by comparison with staying in their kennel. These dogs may be so attached, or suffer so severely on separation from, their care giver or handler, that simply being handled may have had a net positive effect, outweighing any negativity of the veterinary examination. Similar effects have been found in laboratory cats [34] which showed decreased C/C in response to restraint, handling and blood sampling, attributed to the rewarding properties of being held during blood sampling. Since human contact has been shown to reduce stress in dogs (e.g. [35,36]) this is plausible. The same aspects of the dogs' temperament or past experience, for example their propensity for attachment to humans, or aversion to the kennel environment, which led them to show the inverse trace, may also have led them to develop "stereotypical" behaviour.

Inverse cortisol responses to stressors have not previously been reported in dogs, but the dogs' baseline C/C levels were within the "normal range" (e.g.[24]), so whilst we hypothesise that this group may have suffered more due to the effects of long-term kennel stress, it is also possible that these "stereotyping" animals were utilising repetitive behaviours as a coping mechanism and thereby coping best — as has been seen in many other species [2]. New paradigms such as cognitive bias (e.g.[37]) may be useful in elucidating the welfare status of "stereotyping dogs" compared to their non-stereotyping counterparts.

These results also raise the question as to why regular husbandry events elicited such high amounts of repetitive behaviour, and why dogs which did not otherwise spin, pace or bounce, or show any specific evidence of physiological distress, did so at times of feed preparation, or when care assistants were walking past (with or without dogs). One explanation is that these are simply times of high arousal, and animals have previously been shown to increase repetitive behaviour when aroused [38]. In addition, food preparation and delivery were integral to these stimuli and pre-feeding pacing has been documented in various species [33] and has been suggested to be derived from the appetitive search phase of hunting [39–41]. The origins of the behaviours may also be important. Bouncing (with or without rotation) when a care assistant or a dog walks past their kennel, may have begun when the dog jumped to either see out or to defend its kennels from the passer-by. However with time, the behaviour may have become emancipated from the original cause. Repetitive behaviours in other species have been suggested to result from a desire to gain access to con-specifics [33] and stereotypical jumping behaviours have previously been hypothesised in laboratory dogs to be a result of frustrated attempts to see out of the kennel [13]. Also for some of the dogs, the behaviour may have originated in a different environment and is a "behavioural scar" [2] unrelated to the current environment.

A further possibility is that humans have inadvertently rewarded dogs for showing repetitive behaviour, during husbandry procedures. Dogs have been selectively bred to find human attention rewarding (e.g. [42]) yet when kept in a kennel environment, human contact is limited. It is possible that carers have paid additional attention (or delivered food) to dogs that were spinning, bouncing or circling, thereby rewarding or reinforcing the repetitive behaviour, as suggested for pet dogs [17]. Hence in dogs, many repetitive behaviours may be performed because they have been externally rewarded, with the exception of those performed under minimal stimulation which may involve the internal rewards proposed for stereotypical behaviour [2]. There is also the possibility that living in such close proximity, many dogs acquire repetitive behaviour via social transmission from conspecifics as has been seen in bank voles (*Clethrionomys glareolus*; [43]). Overall, social transmission and inadvertent rewarding may explain much of the repetitive behaviour observed in this study.

5. Conclusion

The lack of uniformity in the form and intensity of repetitive behaviour, and in the triggering stimuli, in this population of dogs suggests that such behaviour is unlikely to have a single motivation. In particular, those dogs which exhibited spontaneous repetitive behaviours at times of minimal stimulation showed different physiological stress responses to those that performed little repetitive behaviour, or only did so when stimulated by events outside their kennels. The relationship between the performance of repetitive behaviour by dogs and their welfare status therefore requires further investigation.

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