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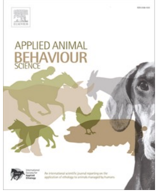

# The impact of auditory distraction on learning and task performance in working dogs

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ABSTRACT

Distractions that lead to performance deficits in working dogs can be life-threatening to the dog, its handler, and others. To reduce the impact of extraneous stimuli, distractors that are likely to occur in the working environment can be incorporated into dogs' training. Yet, the impact that distraction training has on learning efficacy remains unclear. Here, we investigated how training with an acoustic distractor impacts dogs' capacity to learn and later perform a task in the presence of novel distractors. We found that dogs trained with an auditory distractor learned the task less efficiently than dogs trained in silence. Further, dogs trained with a distractor did not perform the learned task more efficiently when tested in the presence of novel acoustic or visual distractors. Dogs trained with an auditory distractor did habituate faster to a novel acoustic distractor during testing compared to dogs trained in silence, but this trend was not significant. Our findings suggest that the initial stages of learning should be conducted in a non-distracting environment to avoid negative impacts on learning.

## 1. Introduction

Working dogs perform a variety of tasks that require them to attend to specific features of their environment whilst disregarding others. When dogs become distracted by extraneous stimuli, their task performance, including accuracy and speed, can become impaired (Snigdha et al., 2012; Mallikarjun et al., 2019; Sheldon et al., , *In review*)). Distractions that lead to performance deficits are particularly concerning for dogs in roles where optimal performance is critical for safety (Haverbeke et al., 2008; Goddard, Beilharz, 1982). Distraction in a guide or detection dogs for example, can potentially be life-threatening to the dog, its handler, and others (Arata et al., 2010).

To reduce the impact of extraneous stimuli on the performance of working dogs, distractors that are likely to occur in the working environment can be incorporated into training. For example, loud noises are gradually introduced to the training of improvised explosive device (IED)-detection dogs (Christensen et al., 2006; Jones and Gosling, 2005). The impact that these training regimes have on learning efficacy remains unclear, but may be expected to reduce learning speed by being distracting. Distraction responses occur when animals are exposed to events or stimuli that are perceived as salient and therefore direct attention away from task relevant information in the environment (Foraita et al., 2021; Phillips et al., 2016). Because attention has a limited capacity, extraneous stimuli can outcompete less salient, but potentially informative task-related cues for processing capacity, thereby inhibiting task-specific learning (Mackintosh, 1975; Pearce and Hall, 1980).

It is also unknown whether training with distractors improves performance in dynamic and often unpredictable working environments. Specifically, it is unclear whether animals are able to generalise from their trained distractors to new distractors they may face whilst working. Stimulus generalisation (i.e., the evocation of a response to a stimulus that is similar to an original conditioned stimulus) is considered exceptionally important for working dogs to maintain performance in a different context to that in which they were trained. Yet, whether dogs reduce the amount of attention they direct towards novel, task-irrelevant stimuli if they vary from one which has previously been established as irrelevant, has not been assessed. This is surprising given that working animals are expected to generalise their training to working environments that often contain many extraneous stimuli (e.g., traffic noise, unstable terrain, smoke etc.,) of varying magnitudes, that cannot all be incorporated into training.

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The aim of our study was to investigate how exposure to a distraction during training impacts dogs' capacity to learn and later perform a task in the presence of novel distractors of varying familiarity. To do this, a simple spatial navigation task, where dogs learned the location of a food reward either in the presence or absence of an auditory distractor, was employed. Dogs were then asked to perform the task in the presence of novel distractors of either the same (auditory) or different (light) sensory modality. We predicted that: i) dogs trained in the presence of an auditory distractor would take longer to learn the task than dogs trained in silence, ii) the presence of a distractor during training would improve task performance in the presence of novel distractors, and iii) performance deficits in the presence of a distractor of the same modality would be less than those in the presence of a distractor of a different modality.

## 2. Methods

### 2.1. Experimental setup

All work was approved by the relevant University Ethics Committee (References 2020–2127 and 2020–2328) at the University of Lincoln (UK) and all experiments were performed in accordance with these guidelines and regulations. Twenty-four dogs were recruited through the 'PetsCanDo' database of volunteers at the University of Lincoln and via social media recruitment. The sample consisted of 14 female and 10 male dogs with a mean age of 5.33 years (SD = 2.95) (see Supplementary Material 1 and 2 for participant details and recruitment requirements).

The experiment was conducted in two connected rooms, separated by a door; a testing room (450 × 500 cm) and a holding room (500 × 900 cm) (Fig. 1). The holding room contained four black, plastic 'buckets' (30 cm high, 34 cm Ø). In the testing room, a Vifa omnidirectional ultrasonic speaker was mounted in the centre of the ceiling (approx. 300 cm high), connected to a Avisoft Bioacoustics USG Player 416 H and controlled using an ASUS Zenbook UX433FA laptop running Avisoft RECORDER USGH software. A Martin Harman Atomic 3000 LED strobe light was mounted on a shelf at a height of 120 cm facing the wall at an angle of 45° at the midpoint of the wall, connected to a programmable ETC ColorSource 20 console. In the centre of the room, on the rubber floor, were three rows of three black plastic buckets (nine in total), each bucket was 120 cm away from the next one (Fig. 1).

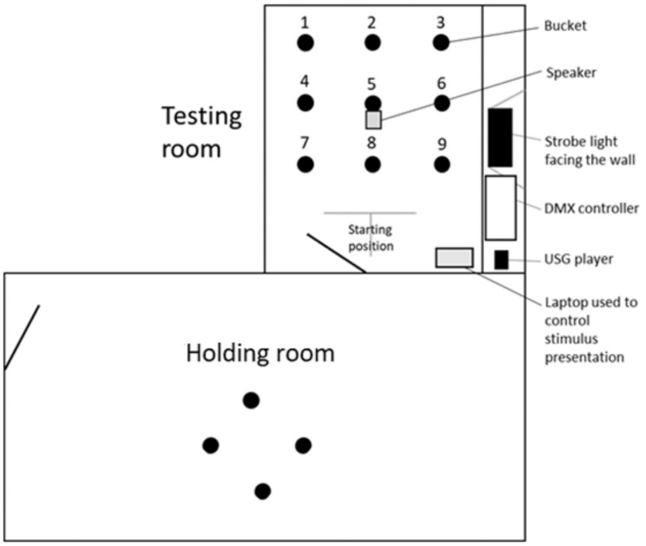

**Fig. 1.** Outline of the experimental arrangement of the testing and holding room. Food rewards were in either Bucket 1 or 3.

### 2.2. Habituation to the experimental set up

Dogs were given 10 min to fully explore and habituate to the two rooms shown in Fig. 1, without the buckets set up but with all equipment present. After this, four buckets were placed on the holding room floor in a diamond shape and dogs were habituated to looking into the buckets for a food reward; a slice of hotdog sausage (approx. 0.5 cm thick) (Fig. 1). Dogs were shown the sausage reward being placed into one of the buckets and the dog was allowed to put its head into the bucket and eat the reward. Whilst the dog's head was inside the bucket, a different sausage slice was placed inside the other buckets for the dog to eat. This continued until the dogs were confidently checking all buckets for the reward, after which the buckets were removed from the room.

### 2.3. Training

Before each trial, either Bucket 1 or 3 (Fig. 1; counterbalanced across dogs for standardisation) was designated as a goal bucket and was baited with a sausage slice reward which could be eaten by the dog when the goal bucket was correctly identified. For each dog, the location of the accessible reward sausage was in the same bucket - hereafter the '*goal bucket*', during every trial. Each 'bucket' in fact refers to two stacked buckets (one sitting within the other). Five holes were drilled in the bottom of the inner bucket such that an inaccessible piece of hotdog sausage could be hidden between the stacked buckets as an odour control for non-goal buckets (i.e., to ensure that the dog was not selecting the goal bucket based on scent). The stacked bucket pair is referred to as a 'bucket' hereafter for simplicity.

When the trial commenced, dogs were led from the holding room into the testing room and positioned at the starting position in a forward-facing stance with the experimenter standing behind them (Fig. 1). Dogs were then released and given unlimited time to check the buckets until the goal bucket was selected (when the dogs nose passed the brim of the bucket and lowered its head into the bucket), which also marked the termination of the trial. Dogs were then led out of the training room to the holding room while the experimenter re-baited the same bucket. After around 30 s in the holding room, a new trial commenced.

#### 2.3.1. Training condition

Twelve dogs carried out training in silence, and twelve dogs carried out training in the presence of a soundtrack (60 dB) - a small group of people clapping or cheering (specific stimulus counterbalanced across subjects). Dogs were randomly assigned to each condition. The sound track was initiated when the dogs were released from the starting position and was terminated when the goal bucket was selected. Hereafter, we refer to each training condition as in '*silence*' or '*sound*'. Trials continued until the dog passed training (i.e., reached criterion) by correctly identifying the goal bucket without checking any other buckets, on three consecutive trials.

### 2.4. Test condition

After dogs reached criterion, they were given five test trials in which they were exposed to a novel acoustic stimulus (a soundtrack that was not used for that animal during training) and then they were given five test trials in which they were exposed to a novel visual stimulus (a strobe light with a brightness of 100,000 lux and flash rate of 5 Hz) (ten trials in total, five trials for each stimulus). 12 dogs were pseudo-randomly chosen to be exposed to the novel acoustic stimulus first, and 12 dogs were exposed to the visual stimulus first; 6 from each condition. The ordering of stimuli exposure was pseudo-random to control for potential carryover effects. During all testing trials, the procedure was identical to training, with the exception that the different distracting stimuli were used. The onset and offset were identical to that used in the *sound* training condition.

### 2.5. Data collection

Three closed-circuit television (CCTV) cameras recorded training and testing which were mounted on the ceiling of the testing room. One camera was positioned directly over the dogs' head when they were in the starting position. The other camera was positioned over the buckets to capture which buckets dogs checked. The final camera captured the precise moment that they selected the goal bucket. All cameras streamed to a HIKVISION digital video recorder which recorded them as separate videos. Individual videos were synchronized and collated into a single video using the VSDC Free Video Editor software. Video recordings of the experiment were imported into the video analysis package BORIS (version 7.9.7), and a continuous sampling technique was used to collect data on:

i. Trial commencement (the moment dogs were released by the experimenter)
ii. The number of non-target buckets checked (the number of times a dog's nose passed a non-goal bucket brim and lowered its head into a non-goal bucket).
iii. Trial termination (the moment dogs selected the goal bucket)
iv. When dogs passed training (when dogs selected the goal bucket directly on three consecutive trials)

To ensure coding was repeatable between two researchers, 4 out of the 24 dogs (16.7% of recordings) were coded independently by each researcher. The inter-observer reliability of trial duration analysed using Pearson's correlation coefficient test was high ($r_{72} = 0.99$, $p < 0.001$). The inter-observer reliability of bucket choices was assessed using Cohen's Kappa coefficient, and was also high ($k_{72} = 0.98$, $p < 0.001$).

### 2.6. Statistical analysis

#### 2.6.1. Training

Our first aim was to investigate whether training condition (*silence* or *sound* (the acoustic distractor)) was related to task learning. We quantified the rate of task learning as i) the number of buckets checked before criterion was met, ii) the rate of learning = the time taken to meet criterion, and iii) the total number of trials before criterion was met. We used the lm() function in R to fit three linear models with each proxy of learning set as the dependent variables. Training condition and dog age were included as fixed effects (age was included as it has been shown to affect performance and learning in the presence of distractors in a previous study (Snigdha et al., 2012).

To assess whether training condition impacted task performance once the dogs had learned the task, we fit a linear model (LMM) in the lme4 package in R (Bates et al., 2015), with 'average trial duration during criterion' (i.e., the average time taken to complete the final three trials of training where the dog correctly identified the goal bucket without checking any other buckets) as the dependent variable, and training condition as the fixed effects.

#### 2.6.2. Test trials

Our second goal was to investigate how training condition impacted task performance in the presence of either a *novel sound* (same modality) or *light* distractor (different modality). We quantified how each test condition impacted task performance by calculating two proxies i) the difference between the time taken for a dog to complete a testing trial versus the average time it took to complete the last three (criterion meeting) trials, and ii) the number of buckets checked per trial (the number of buckets checked during criterion meeting trials was always zero - the condition of meeting criterion). We used the lme package in R to conduct two separate LMMs with i) 'Trial duration during testing compared to criterion' and ii) 'Number of buckets checked during testing' as dependent variables. In both models, trial number (one to five), training condition: *silence or sound*, test condition: *novel sound, or light*, and dog age were included as fixed factors. An interaction between training condition and trial number and testing condition and trial number was included in both models. This allowed us to assess how training condition impacted testing with a novel sound or light, and how varied over time (i.e., whether training in sound increased the rate of habituation to testing with a *novel sound* and/or *light* compared to training in silence). (To ensure our model was not over-parameterised, we also run two separate models each testing condition: *novel sound* and *light* consistent. These separate models generated consistent statistical outputs to the singular model despite its high parameterisation, we therefore decided to report the single model which also compare performance between testing conditions). We included dog identity as a random effect in both models to account for repeated measures of the same individual.

All statistical analyses were conducted in R 4.1.2 (R Development Core Team, 2022). The R packages 'lme4′ and 'lmerTest' were used to conduct linear models and linear mixed models (Bates et al., 2015; Kuznetsova, . et al., 2017). Before conducting analyses, we used the R packages 'olsrr' and 'lmtest', to visually inspect residual vs fitted values plots and conducted Shapiro-Wilk and non-studentized Breusch-Pagan analyses (Razali and Wah 2011). These tests indicated that the residuals of our regression analyses were normally distributed and homoscedastic. Breed was included as a fixed effect into our initial models; however, this factor was not related to the rate of learning or task performance in any of the analyses. It was therefore removed from our models to avoid over-fitting (24 dogs participated in our experiment, comprising 14 different breeds, the inclusion of 'breed' as a fixed effect led to too many terms for the number of observations and the regression coefficients representing the noise in the data, rather than the actual relationship between the dependent and fixed/random effects).

## 3. Results

### 3.1. Training

Dogs took significantly fewer trials to pass training in *silence*; taking on average a total of 18.57 trials (SD=3.48) to complete training in *silence* and an average of 31.03 trials (SD=9.19) in *sound* (see Table 1a for statistical results, Fig. 2). Dogs trained in *silence* also checked on average, less buckets before passing training criterion (an average, total of 39 buckets (SD=17.76)) compared to dogs trained in *sound* (checking on average, a total of 55 buckets (SD=23.56)), though this difference was not significant (Table 1b). Dogs in the *silence* condition took less time to learn the task, taking an average of 184 s (SD=111.54) to complete training, while dogs in sound took an average of 252 s (SD=23.56), this difference was not statistically significant (Table 1c). Together, these results suggest that dogs learned the task more

**Table 1**

The relationship between a) the total number of trials before passing training, b) the total number of buckets checked during training, and c) total duration of training, and the fixed effects. Estimates reflect the effect size of each fixed effect (i.e., the estimates show the effect of a one unit increase in the fixed effect on the dependent variable). Positive values associated with (*sound*) indicate that dependent variable was lower in the *silence* condition compared to the *sound* condition. (*) = statistically significant effects.

| Fixed effects | Estimate (SE) | *t*-value | *p*-value |
|---|---|---|---|
| 1a) Dependent variable: Total number of trials to complete training | | | |
| Training Condition (*sound*) | 9.207 (1.328) | 6.931 | < 0.001 * |
| Dog Age | 0.325 (0.256) | 1.258 | 0.227 |
| **1b) Dependent variable: Total duration of training** | | | |
| Training Condition (*sound*) | 72.319 (65.072) | 1.111 | 0.282 |
| Dog Age | -5.381 (−12.561) | -0.428 | 0.674 |
| **1c) Dependent variable: Total number of buckets checked** | | | |
| Training Condition (*sound*) | 15.027 (10.434) | 1.440 | 0.169 |
| Dog Age | 1.786 (2.014) | 0.887 | 0.388 |

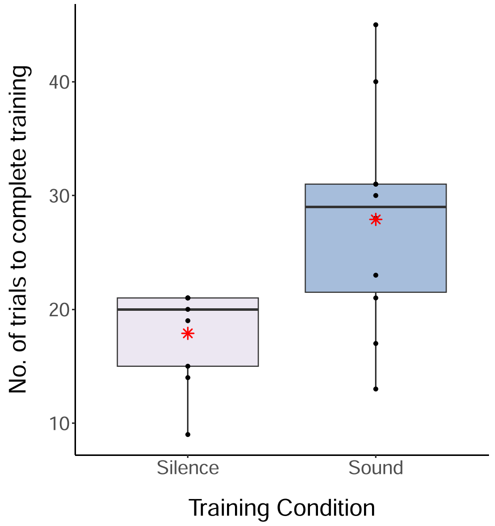

**Fig. 2.** The total number of trials before completing training for dogs trained in the *silence* and *sound* condition. Red (*) represents mean values, error bars are the 95% confidence interval, and the horizontal box lines represent the 25th, 50th (median), and 75th percentiles.

effectively in the *silence* condition compared to the *sound* condition (Table 1). Dog age was not related to learning (Table 1).

There was no significant difference in the time taken to complete criterion meeting trials between the conditions (estimate = 0.470 (SD=0.338), t = 1.389, p = 0.167) suggesting that, upon learning the task, all dogs were performing at comparable levels. On average, criterion meeting trials took 3.74 s (SD=4.24) in the *sound* condition, and 3.50 s (SD=3.83) in the *silence* condition. Dog age was not associated with the time taken to complete criterion meeting trials (estimate = −1.261 (SD=0.065), t = −1.930, p = 0.091).

### 3.1.1. Test trials

Compared to criterion, dogs took significantly longer to complete test trials in the *novel sound* condition compared to *novel light* condition (see 'Test condition (*novel sound*)' in Table 2). Dogs took on average 4.41 (SD = 4.23) seconds testing trials with the *light* distractor, and an average of 7.97 s (SD = 13.54) when tested with a *novel sound*. The time taken for dogs to complete each trial decreased significantly across *novel sound* test sessions (see Fig. 3 and the interaction between test condition*trial, Table 2a), suggesting that dogs rapidly habituated to this distraction. While dogs trained in *sound* habituated faster to the *novel sound* distractor than dogs trained in *silence* (Fig. 3), this trend was not significant (see the interaction between training condition (*sound*) and trial in Table 2). Training condition did not impact task performance relative to criterion when tested with a *novel sound* or *light,* nor did training condition affect change in performance over time (see the three-way interaction between 'Training Condition (*sound*), test condition (*novel sound*) and Trial in Table 2a). This indicates that dogs trained with the *sound* distractor did not perform better or habituate significantly faster to the similar or dissimilar distractor. The marginal $R^2$ value for this LMM (Table 2a) is 0.169, while the conditional $R^2$ values (describing the percentage of total variance in the data the model explains) was 0.274. These R2 values indicate that the fixed effects explained 16.9% of variance in trial duration during testing compared to criterion whereas the random effect od dog ID explained the remaining 10.5% of variation.

**Table 2**
The effect of training and testing condition on trial duration during testing compared to criterion. Estimates reflect the effect size of each fixed effect (i.e., the estimates show the effect of a one unit increase in the fixed effect on the dependent variable). Positive values associated with (*novel sound*) or (*sound*) indicate that dependent variable was greater in the *novel sound* or *sound* condition compared to the *light* or *silence* condition, respectively. (*) = statistically significant effects. ($^{x}$) represents interaction terms.

| 2a) Dependent variable: Trial duration during testing compared to criterion | | | |
|---|---|---|---|
| Fixed effects | Estimate (SE) | *t*-value | *p*-value |
| Trial Number | -0.063 (0.838) | -0.075 | 0.940 |
| Training Condition (*novel sound*) | -0.926 (3.372) | -0.275 | 0.784 |
| Test Condition (*novel sound*) | 12.747 (3.153) | 4.042 | < 0.001 * |
| Dog Age | -0.373 (0.345) | -1.078 | 0.296 |
| Training Condition (*sound*)$^{x}$ Trial | 0.193 (0.954) | 0.203 | 0.839 |
| Test Condition (*novel sound*)$^{x}$ Trial | -2.879 (0.953) | -3.021 | 0.002 * |
| | **Random effect** | **Variance** | **SD** |
| | Dog Name | 6.192 | 2.488 |
| **2b) Dependent variable: Number of buckets checked during testing** | | | |
| **Fixed effect** | **Estimate (SEM)** | **t-value** | **p-value** |
| Trial Number | -0.022 (0.074) | -0.028 | 0.512 |
| Training condition (*novel sound*) | -0.110 (0.352) | 0.473 | 0.639 |
| Test condition (*novel sound*) | 0.373 (0.279) | 1.337 | 0.183 |
| Dog Age | 0.044 (0.04) | 0.940 | 0.361 |
| Training condition (sound)$^{x}$Trial | -0.058 (0.084) | 0.070 | 0.945 |
| Test Condition (*novel sound*)$^{x}$ Trial | -0.056 (0.084) | -0.675 | 0.501 |
| | **Random effect** | **Variance** | **SD** |
| | Dog Name | 0.212 | 0.461 |

The number of buckets checked during testing was not associated with testing modality (*light* or *novel sound*), training condition (*sound* or *silence*), or dog age, and did not differ between trials (Table 2b).

## 4. Discussion

The aim of our study was to assess how auditory distraction impacts dogs' capacity to learn and later perform a task in the presence of novel distractors. We found that dogs trained with an acoustic distractor required significantly more trials to learn a simple spatial navigation task compared to dogs trained in silence. However, once dogs learned the task (i.e., met criterion), dogs from both training conditions performed comparably. Contrary to our predictions, dogs trained with an acoustic distractor did not perform better than dogs trained in silence when tested with a distractor of the same (acoustic) or different (light) modality. Interestingly, during testing, only the acoustic distractor

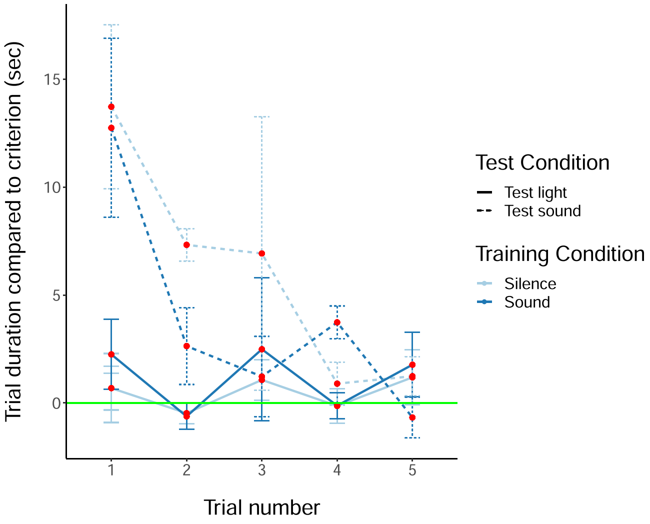

**Fig. 3.** The difference in trial duration during testing compared to criterion-meeting trials (x-axis) across the five testing trials (y-axis). The light blue solid and dashed lines represent trial durations for dogs trained in silence when they were tested in light and sound, respectively. The dark blue solid and dashed lines represent trial durations for dogs trained in sound when they were tested in light and sound, respectively. Error bars represent the standard error of the mean. Red dots represent the mean variation in trial duration from criterion to testing. Values above the horizontal green line indicate that trial duration was greater during testing than criterion meeting trials.

reduced dogs' task performance in relation to that achieved during criterion; the light distractor did not impact performance. While dogs trained with an acoustic distractor did tend to habituate faster to the novel acoustic distractor than dogs trained in silence, this trend was not significant. Our results, therefore, provide limited support for the idea that initial training with distractors improves task performance in the presence of novel task-irrelevant stimuli. Instead, our findings highlight the potentially negative effects that training with a distractor can have on initial learning. Previous research has suggested that in situ (in distraction) training is important for final performance (Mentis et al., 2016; Burrows et al., 2008), our works highlights that initial learning should be conducted in a non-distracting environment before transition to a distracting environment once criterion is met.

In line with our predictions, the rate of learning a simple spatial navigation task was greater in dogs trained in silence compared to those trained in the presence of an acoustic distractor. To our knowledge, no previous research has investigated the consequences of acoustic distraction on learning in dogs. However, in humans, the negative impact of auditory distraction on cognitive processes is well established (Kämpfe et al., 2010; Threadgold et al., 2019). Two theories have been proposed to account for these effects: the *Cognitive-Capacity model* and the *Arousal-Mood hypothesis*. The arousal-mood hypothesis largely refers to the potential emotive effects of sound on task performance and behaviour (Proverbio et al., 2015); however, such effects are inconsistent and/or age-dependent among humans (Bottiroli et al., 2014; Reaves et al., 2015) and dogs (King et al., 2022). The cognitive-capacity model on the other hand, postulates that only a limited pool of resources is available for cognitive processing at any given moment. Thus, when concurrent tasks compete for these resources, their combined demands may exceed that available to process a significant amount of task information, potentially leading to performance deterioration. Previous research has shown that dogs are more responsive to human vocalisations with a positive valence (Albuquerque et al., 2016). Exposure to the acoustic distractor in our study (a 60 dB soundtrack of a small crowd clapping and cheering) is therefore likely to have increased arousal levels in the dogs. However, exposure to the acoustic distractor was not associated with improved learning, and our results therefore do not align with the arousal mood hypothesis. Our findings are more supportive of the cognitive-capacity model; that the acoustic distractor was likely to have interfered with task performance by overloading attentional systems.

The amount of attention that a stimulus can capture is determined by a range of factors contributing its overall salience; one of which is prior learning history. According to the Mackintosh (1975) cognitive capacity model, animals direct more attention towards stimuli that have been established as good predictors of important events than those that do not. For this reason, it was anticipated that dogs exposed to sound during training would be less affected by the presence of a novel sound distractor during testing, compared to dogs trained in silence. While dogs trained with sound did perform better in, and habituate faster to the presence of a novel sound compared to dogs trained in silence, these trends were not significant. It was also expected that dogs trained in sound would be less affected by exposure to novel sounds than to novel lights, as dogs would be more likely to generalise their learning towards a novel distractor of the same modality (Shepard, 1987). Instead, we found that the novel sound significantly reduced task performance in dogs trained in both sound and silence, while exposure to a novel light had almost no impact on task performance. These findings suggest that light stimuli are less distracting than acoustic stimuli regardless of prior conditioning. Indeed, in our recent study (Sheldon et al., , *in review*), light distractors (exposure to a dark adaptation response) did not significantly impair dogs' performance of a visual discrimination task, but exposure to an acoustic distractor did.

Task performance during testing was not contingent on training condition, thus, once dogs reached asymptote, their performance was equally reliable regardless of the condition in which the task was learned. This finding could suggest that dogs did not generalise the novel acoustic stimulus with the stimulus experienced during training - despite the fact that they were similar, steady-state acoustic stimuli made by human crowds (however, dogs may have been sensitive to nuanced differences between the stimuli that human hearing did not detect). Further work is needed to determine the threshold at which acoustic stimuli may differ before generalisation no longer occurs. Dogs rapidly (after one trial) improved task performance when tested in the presence of the novel sound stimulus, possibly suggesting that dogs habituated rapidly to the novel sound. This trend was accelerated in dog's trained in the presence of an acoustic distractor, however, not significantly so. The rate of task completion remained constant across the light trials; however, this is likely because the dogs were already preforming close to capacity in the presence of light- and any room for improvement could not be detected by our statistical analyses.

Notably, while testing and training conditions explained around 17% of variation in task performance, inter-individual variation (independent of these effects) explained 11% variation in the data. Moderate levels of inter-individual variation in response to distraction training suggests that future work should seek to identify intrinsic traits (e.g., low noise aversion) and/or extrinsic strategies (hearing/visual protection more gradual habituation training) that maximise habituation to, and/or mitigates performance impairments of extraneous stimuli.

Previous work on humans and dogs suggests that once a task has been learned, in situ (in distraction) training is important for final performance (Mentis et al., 2016; Burrows et al., 2008). Indeed, habituating animals (e.g., IED-detection dogs) to sudden loud noises during the later stages of training has clear benefits for their performance in the field (Christensen et al., 2006; Rooney, 2016). Our work suggests that distractions during *initial* training (before criterion is met) offers limited benefits for task performance in distracting environments, and may in fact impede learning. Together, we suggest that initial learning should be conducted in a non-distracting environment before transition to a distracting environment once criterion is met. Future research should aim to expand our understanding of the types of distractors that impair dogs' learning, including different modalities (e.g., olfactory, Rutter et al., 2021), durations and intensities. Specific to auditory distractors, it would be useful for dog trainers and handlers to know what types of sound (e.g., biological, mechanical etc.,) dogs find most distracting, and what properties of their wave formations (changes in pitch, volume) are most likely to impact learning and task performance (Tremblay et al., 2000). Notably in humans, the performance deficits of distraction by irrelevant sounds are contingent on the extent of the *changing state effect*; when auditory sequences containing many different objects (such as words or tones) disrupt cognitive performance more than continuous or repetitive sounds (Bell et al., 2019). While we only tested distraction by one acoustic stimulus, the effects of 'steady-state' compared to 'changing state' acoustic stimuli on learning would be an interesting avenue for future research (Campbell et al., 2002).

## Contributions

Each author declares substantial contributions through the following:

(1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, Please indicate for each author the author contributions in the text field below. Signatures are not required. Dr Eatherington (CJE) conceived the idea for the project. CJE, Prof.Mills, Dr Soulsbury and Dr Wilkinson designed the experiment. CJE, Mrs Sumner, and Dr Sheldon (ELS) conducted the experiments and collected the data, ELS analysed the data, ELS and CJE wrote the manuscript, all authors revised the manuscript.

## Approval of the submitted version of the manuscript

Please check this box to confirm that all co-authors have read and approved the version of the manuscript that is submitted. Signatures are not required.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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### *Author contributions*

CJE conceived the idea for the project. CJE, DSM, CS and AW designed the experiment. CJE, RS, and ELS conducted the experiments and collected the data, ELS analysed the data, ELS and CJE wrote the manuscript, all authors revised the manuscript.

### *Approval for animal experimentation*

All work was approved by the relevant University Ethics Committee (References 2020–2127 and 2020–2328) at the University of Lincoln (UK) and all experiments were performed in accordance with these guidelines and regulations.

## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.applanim.2023.105977.

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