

Effects of feeding on dogs' frustration-related behaviours during a laboratory-based scent detection task

Jade Fountain^{a,*}, Journie Yee^b, Susan J. Hazel^a, Todd J. McWhorter^a, Tyler McNutt^b, Timothy L. Edwards^b

^a School of Animal and Veterinary Sciences, Adelaide University, Australia

^b School of Psychological and Social Sciences, University of Waikato, New Zealand

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ABSTRACT

Dogs often use their keen olfactory abilities in laboratory settings to support scent detection research. In cognitively demanding tasks, pre-feeding appears to influence engagement and performance, but the effects of hunger state on dogs' frustration-related behaviour during scent-detection work has not previously been examined. We analysed overall behaviour patterns observed during a laboratory-based scent detection task and evaluated whether dogs exhibited frustration-related behaviour changes as a function of having had breakfast before the task. We expected to see an increase in frustration-related behaviours when dogs were working prior to eating breakfast. Behavioural observations were extracted from video recordings of six dogs participating in the scent-detection task. During the sessions, dogs spent the greatest proportion of time with the tail held low (85%) and still (73%). Whining and engagement with the feeder and scent detection apparatus was higher when dogs had not eaten before the task, consistent with mild frustration, although behaviours varied between dogs and these differences were primarily driven by one or two dogs. Regardless of condition, lip licking and ground sniffing occurred more frequently earlier in the day, with lip licking also increasing over the course of the study. These findings suggest that working prior to a meal may have a mild effect, increasing frustration-related behaviours in some dogs, but additional research is required to clarify potential mechanisms underlying this effect. The low levels of frustration-related behaviours more generally suggest that laboratory scent-detection tasks, similar to the present task, do not reliably evoke such behaviours.

1. Introduction

Dogs play a vital role as sentinels in odour detection, assisting humans across diverse fields, including the detection of narcotics, weapons, invasive and endangered species, missing persons, and disease (Berg et al., 2024). Beyond professional work, companion dogs also participate in scent detection activities for recreation and competition, performing tasks modelled on those used by working detection dogs (Australian National Kennel Council, 2020). These exercises highlight the remarkable olfactory abilities of dogs and the ways in which their natural behaviours can be harnessed for both practical and recreational purposes. Companion dogs participating as canine citizen scientists are increasingly being incorporated into conservation detection (Decker, 2021; Rutter et al., 2021), medical detection (Edwards et al., 2017), pest and invasive species detection (Kane et al., 2023), and civilian search and rescue teams (Jones et al., 2004). Despite the growing field of

investigation into companion dog scent-based activities, there is relatively little research investigating observable behaviours of dogs during trained scent tasks (Fountain et al., 2025a,b).

Canine body language and behaviour during scent detection have been examined with respect to sniff duration (Concha et al., 2014), nostril use during odour investigation (Siniscalchi et al., 2016), sniffing rates, tracking speed and direction (Thesen et al., 1993), and changes in search strategy as odour complexity increases (Mejia et al., 2024). For example, Mejia et al. (2024) assessed search behaviour and stress-related responses in companion dogs trained for scent work and found during localisation of the odour source observed behaviours consisted of visible excitement, exhibited as rigidity in the body posture, increase in breathing rates and sniffing frequency, appearing to be more focused on the task, with some observed frantic behaviour or head turns. Understanding behavioural cues and body language changes during odour detection, beyond trained indication responses to targets and

* Correspondence to: School of Animal and Veterinary Sciences, Roseworthy Campus, Adelaide University, Mudla Wirra Road, Roseworthy, SA 5371, Australia.
E-mail address: jade.fountain@adelaide.edu.au (J. Fountain).

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non-target odours, can improve scent detection performance and support higher-quality handler training, with the aim of reducing frustration in dogs (Waterbury and Schultz, 2022). The potential for a handler to misinterpret changes in behaviour or doubt the dog's response has been suggested as a possible negative factor during scent tasks involving companion dogs (Fountain et al., 2025a,b). Such observable behaviours are likely to vary across individual dogs, breeds, and the diverse forms of trained indication and rejection responses. If a handler fails to recognise the change in behaviour when the dog perceives the odour and within the series of responses that occur up to a dog indicating on an odour source, then the handler could redirect the dog elsewhere and miss the odour (Martvel, Pedretti, et al., 2025). For example, tail carriage is considered a relevant behavioural indicator in scent detection contexts, as tail movement patterns provide cues regarding odour engagement, although expression varies across individuals (Martinez and Hartell-DeNardo, 2008; Martvel, Pedretti, et al., 2025). Further investigation into these differences could enhance scent work performance and outcomes, both in operational settings and recreational contexts.

Dogs communicate using their whole body in interactions with both conspecifics and humans, with a large repertoire of behaviours and body postures that can signal changing needs within their environments and information about their current state (Beerd et al., 1998; Flint et al., 2024; Siniscalchi et al., 2018). Behaviour is commonly used as a measure of welfare to assess coping responses to physical and social stressors (Albuquerque et al., 2018; Beerd et al., 2000). An animal's behavioural responses to a given learning task and environment can serve as indicators of the animal's physiological and emotional state and can also influence performance in the task. Stress responses to environmental or internal demands manifest as a suite of physiological and behavioural changes, including observable behaviours (e.g., changes in posture, activity, avoidance, and vocalisation) and measurable physiological indicators such as autonomic responses (Cobb et al., 2025; Kartashova et al., 2021). The emotional experience accompanying physiological arousal is valenced and may reflect either positive or negative stress states (Mendl et al., 2010). Stress-related behaviours should be understood as dynamic expressions of underlying affective processes, encompassing multiple frameworks including fear, anxiety, frustration, conflict, heightened arousal, and responses to ambiguity or excitement (Kartashova et al., 2021).

Within the negative stress framework, frustration and displacement behaviours are recognised as stress-related behavioural profiles. In addition to frustration, displacement behaviours represent another stress-related state, defined as actions displayed outside their normal context and lacking immediate functional relevance (Pedretti et al., 2022). In dogs, common displacement behaviours include self-grooming, scratching, yawning, lip licking, environmental sniffing, and object manipulation (Aloff, 2018). Frustration, described by Amsel (1992) as an aversive motivational state arising when an anticipated reward is withheld, reduced, or delayed, and can occur under conditions of inconsistent reinforcement. In scent detection tasks, reinforcement is contingent on indication responses in the presence of a target odour, meaning dogs may not receive a reward on some trials despite searching or engaging in sniffing to discriminate an odour. Under these "frustration" conditions, dogs might display increases in vocalisations, activity and behaviour patterns may intensify, or an individual may withdraw from engaging in the task (Jakovcevic et al., 2013). For instance, omission of food in training led to an increase in dogs lying down, whining, walking around more, and sniffing the environment (Jakovcevic et al., 2013). Frustration-related behaviours increase during trial-and-error discrimination tasks, when error rates are higher (Handley et al., 2023). Search and rescue dogs exposed to a frustration-inducing condition showed reduced performance, increased error rates, increased heart rate and decreased heart rate variability, indicating arousal, reduced welfare and short-term stress (Dickinson and Feuerbacher, 2025). Many of these behaviours are also commonly listed as indicators of negative stress, making it challenging to disentangle

whether they reflect arousal, or other emotional states; interpretation requires consideration of the broader behavioural context and concurrent physiological measures.

Frustration-related behaviour is typically defined with reference to contexts with reduced reinforcer availability. It stands to reason that other reinforcer-related factors, such as changes in the quality or magnitude of reinforcers, may also influence the expression of frustration-related behaviours. One such factor is the temporary effectiveness of a reinforcer, which can be altered via motivating operations such as food deprivation or satiation (Edwards et al., 2019). Given that dogs work under varying states on the hunger-satiation spectrum, it would be particularly useful to examine the influence of this factor on frustration-related behaviour. One might anticipate that eating prior to working, which may "devalue" food reinforcers, may reduce frustration-related responses when a response is not reinforced. Further investigation of the influence of this factor on frustration-related behaviour within scent-detection contexts is warranted.

1.1. The breakfast effect

Eating a meal helps regulate blood sugar levels, supports healthy metabolism, and manages hunger cues. Additionally, it can enhance cognitive function, improve attention span, boost memory and recall, and overall performance (Miller and Bender, 2012). Dogs fasted for 90 min were less accurate in recalling the hidden location of a treat than dogs that were fed 30 min prior (Miller and Bender, 2012). At 90 min post-meal, dogs performed similarly to dogs fasted for 12 h. The authors suggested that cognitive task performance may depend on glucose availability, due to increased energetic demands or elevated motivational arousal, with performance varying in line with the Yerkes-Dodson law (which describes an "inverted U" function whereby the highest performance is obtained within a zone of optimal arousal, neither too high nor too low). Dogs in laboratory scent detection tasks are often taught to self-direct in a trained behaviour chain with no human handler present. The individual has control over their environment to interact with the scent apparatus and receive reinforcement contingent upon accurate positive indications, such as correctly indicating a target odour. Upon recognising a negative sample, the individual may initiate a sample change by moving to the next sample (e.g., on a stationary carousel) or engaging a lever (on an automated apparatus). Alternatively, the dog can opt out of the opportunity for reinforcement by not participating. Examining the effects of pre-task meals on a cognitively demanding scent detection task, conducted without a handler present, allows assessment of dogs' engagement and behaviour independent of human influence.

This study aimed to investigate whether: 1) there are consistent overall behaviour patterns indicative of stress or frustration observed during a laboratory-based scent detection task, and 2) frustration-related behaviour changes as a function of having had breakfast before a scent detection task in companion dogs. Relevant to the second aim, we hypothesised that more frustration-related behaviours would be observed when dogs have not had breakfast before engaging in a scent task.

2. Method

2.1. Ethics statement

The original experimental procedure was approved by the University of Waikato Animal Ethics Committee (Protocol 1227). The use of video data was within the scope of the original study's ethical clearance.

2.2. Study design

This study used existing video footage obtained during a separate study, which investigated the effect of a recent meal on dogs'

performance in a scent detection task within a laboratory setting using an automated apparatus (Yee et al., 2026). The data used in the present study were collected by coding dog behaviours from videos recorded during the experimental sessions.

2.3. Subjects

Six pet dogs from across the Waikato community were recruited into the original study assessing the effect of a recent meal on scent detection performance. Dogs lived with their caregivers, who brought their dogs into the laboratory for two mornings each week. The dogs that participated and were included in the current study include six breeds, consisting of three male and three female dogs (See Table 1). The mean age was 2 years, ranging from 6 months to 8 years. Previous learning history was provided by caregivers. Mika had some prior scent detection experience; Darla had participated in a visual discrimination task. Ora had prior service dog training and Ludo had previously engaged in trick dog training.

2.4. Scent detection study: setting and procedure (Yee et al., 2026)

Dogs were housed in individual kennels with bedding and free access to water in a kennel room with up to three other dogs. The experimental room measured approximately 3.1 by 3 m. Prior to participating in the experiment, dogs were habituated to the researcher, the kennel, the experimental room, and the apparatus. Temperature in the facility was maintained at approximately 22° C. Caregivers were instructed not to feed their dogs in the morning on days the dogs were participating in the study. Researchers were provided with the dogs’ normal breakfast food and amount, and dogs were fed in the lab based on the condition that they were participating in that day. For the aims of the original study, dogs were trained to perform a scent discrimination task so that their scent-detection accuracy as a function of the breakfast condition could be examined. Dogs were trained to use an airflow olfactometer, a 30 cm³ device that housed six odour vials and could deliver any combination of the six odours into an airstream, which was released into an odour port, where dogs could sample the odours (Fig. 1). An infrared beam inside the odour port was used to record interactions with samples. An infrared beam break of a specified duration (customised for individual dogs) was treated as an “indication” response. A shorter beam break threshold was used to confirm that the dog had sampled the odour; after sampling the odour, dogs could pass to the next trial by activating an omnidirectional lever positioned on the right side of the cube. This device was based closely on the design reported by Aviles-Rosa et al. (2021) but modified to allow for an explicit rejection response via the omnidirectional switch. Once dogs were competent on the task, the main researcher entered the room only when a dog had been off task for five minutes, briefly cueing the dog back to the scent apparatus before leaving. Otherwise, dogs completed the behaviour chain independently of prompting.

When the target odour mixture was present, correct indications or “hits” (breaking the port beam for the specified duration) were reinforced via a Treat and Train (PetSafe) kibble dispenser or a custom carousel feeder which was positioned directly behind the dogs, 1.5 m opposite the olfactometer. If the target was present but the dogs pressed

the lever before sniffing the sample for the required duration (a “miss”), no reinforcer was delivered. Treats used for reinforcers were: dry kibble, Possyum loaf (Superior Pet Food Co., NZ), and peanut butter and cranberry treats (Awesome Pawsome, NZ). When the target odour mixture was not present, an indication response was recorded as a false indication, but it had no programmed consequences, and a lever activation was required to pass to the next trial. Pressing the lever prior to indicating was recorded as a correct rejection, but correct rejections were not reinforced (see Edwards et al., 2022 for an explanation of the rationale for this type of task). Once trained to operate the scent apparatus, no human input was required and, in general, the handler observed the session from an adjacent room (the kennel room) via live video feeds from two cameras (which produced the footage used in the present study). Sessions consisted of 20 trials, 10 target and 10 non-target trials.

The odours used in the study were: amyl acetate, benzaldehyde, hexanol, benzyl acetate, butyl acetate and ethyl butyrate. The target odour was a combination of the first four odours. Non-target mixtures increasingly overlapped with the target mixture as task complexity increased, with 46 potential non-target combinations. Task complexity was increased to prevent a ceiling and floor effect in the scent detection study. Dogs were trained across three training components and up to five phases (of progressively increasing complexity, as required) in a single subject alternating treatment design where they were exposed to two conditions (see supplementary material S1). The two conditions were pre-breakfast or post-breakfast. In the pre-breakfast condition, dogs completed experimental sessions prior to having their morning meal. Dogs were then fed at 11:50 am, after sessions. In the post-breakfast condition, dogs were given their meal at 9 am, prior to their experimental sessions. Regardless of the condition that was in effect, experimental sessions occurred within the same time window each day. Dogs participated in two training sessions per week. The order of pre-breakfast and post-breakfast conditions was counterbalanced; for every two-week period, conditions were presented in one order in a randomly determined week and in the other order on the remaining week.

Sixty-eight hours and fifty-five minutes of videos across all dogs participating in the scent detection study over ongoing sessions, up to 4 times per week, from April to October 2025, were available for analysis. Footage was analysed from videos of experimental phases of the initial study. No videos were used during the early training phases when dogs were learning odour discrimination, shaping a nose hold indication or operating the lever for non-target odours (See supplementary material S1 for detail on training phases and S2 table showing a breakdown of sessions per condition used in analyses).

2.5. Video footage

Two cameras (Logitech HD Pro C920) were positioned at two side-on angles, approximately 2 m from either side of the olfactometer/feeder, to capture the right and left side of the dog while engaged in the detection task (Fig. 1). One camera was positioned 1.9 m above the floor and the other at 0.9 m above the floor. Sessions lasted from 3 to 15 min and sessions were excluded from analysis if they were shorter than three minutes in duration (See S6 for example of session).

2.6. Measures

2.6.1. Behaviour coding

An ethogram was developed after review of the literature (Table 2), which focuses on capturing known stress-related behaviours and frustration based on prior research with dogs and canine body language resources (Aloff, 2018; Beerda et al., 1997; Handelman, 2012; Krauss and Maue, 2022; Rugaas, 2006). Some known stress-related behaviours were excluded (e.g. paw lift) as it was deemed they likely serve a social communicative function, and as most sessions had no humans present

Table 1
Dog demographics for canine participants.

Dogs name	Breed	Sex	Age
Ludo	Whippet mix	Male desexed	3 years
Buddy	Cocker spaniel	Male desexed	3 years
Kal	Mixed	Male desexed	18 months
Mika	Border collie mix	Female desexed	8 years
Ora	Labrador	Female desexed	1 year
Darla	Fox terrier mix	Female desexed	7.5 years

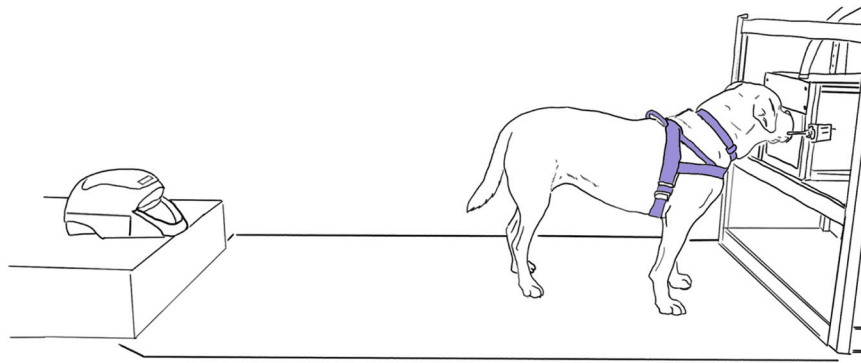


Fig. 1. Experimental setup of scent detection olfactometer scent apparatus showing the nose in the port, adjacent lever and the Treat and Train feeder. Illustration by Jade Fountain.

and never had other dogs present, these behaviours were likely not to be seen, or were unable to be seen from the quality and angle of the cameras (e.g. blinking, furrowed brow or facial muscles).

Behaviours were coded in a continuous focal sampling method via either duration (in seconds), recording onset and offset of a particular behaviour, or for each occurrence observed (count), which was used to calculate frequency of behaviour (Martin and Bateson, 2014). Behavioural data were summarised separately for duration and frequency measures.

Dog behaviours were grouped into 6 categories consisting of tail position and movement, vocalisation, body posture (e.g., laying down, shake off, sit), facial/mouth (e.g., yawn, pant), ear position and other (e.g., orientation to stimuli or out of view). If a dog was out of view of the camera or left the threshold of the door (during earlier sessions in training phases, the door was open and dogs could leave the room at any point), they were marked out of view. Vocalisations were included for analysis for September onwards, as audio was not captured by the cameras until this time. This equated to 112 sessions with whining recorded.

2.6.2. Video analysis

To code the videos, we used BORIS (Behavioural Observation Research Interactive Software) version 7.9.19 (Friard and Gamba, 2016). Researchers used an ethogram to code observed behaviours during the session. Each video was coded after a training phase for raters, during which inter-rater reliability was evaluated for 20 videos randomly selected from Kal, Buddy, Ludo and Ora's footage (5 videos each). Subsequently, additional training on the coding process was conducted, and the ethogram was refined, which involved establishing more precise operational definitions and removal of behaviours (Cole, 2023) until satisfactory inter-rater reliability was achieved (ICC moderate to excellent > 0.50 ; Koo and Li, 2016; See supplementary material S7). One researcher coded all videos, and a second researcher coded 20% of videos to allow for calculation of inter-rater reliability. Ear position was dropped from subsequent analysis due to poor reliability (ICC < 0.50) after the training phase. Ear position was considered a meaningful indicator to include when assessing stress-related behaviours (Aloff, 2018); however, the wide variation in breed and physical characteristics such as drop or pointed ears, and dogs with dark colouration, posed challenges for observers to accurately code ear positions. Stress-related behaviours were considered as lip licking, yawn, shake off, whining, sniff ground, stretch and groom. Bark, pant, groom and stretch were dropped from analysis as these behaviours were rare or never occurred. Laying down (head up or down) was pooled into one category of lay, all feeder behaviours (sniff, stare, paw or lick) were also pooled as one feeder interaction category. Coders were blind to the conditions during sessions while analysing the videos.

2.6.3. Data analysis

To evaluate inter-rater agreement, ICC Intraclass correlation coefficient estimates and their 95% confident intervals were calculated using SPSS (Version 29.0.1.0; SPSS Inc, Chicago) based on a mean-rating ($k = 2$), absolute agreement, two-way mixed effects model of agreement between two raters and multiple measurements (Harvey, 2021; Koo and Li, 2016). ICC values were interpreted as poor (ICC < 0.50), moderate (ICC $0.50-0.75$), good (ICC $0.75-0.90$), or excellent (ICC > 0.90) (Koo and Li, 2016). See supplementary material S7 for exact measures for each behaviour. We investigated the influence of the breakfast condition on 14 observed behaviours, including duration and frequency measures, while controlling for time elapsed since 9 am and days since project start. The unit of analysis was the duration or frequency measure obtained in each session for each dog (for example, the cumulative duration of sitting or the frequency of sitting in a single session). Behaviours analysed as duration were tail movement and position (high, low, still, wag), sit, lay, orientation to door and whining. Behaviours analysed as frequency counts were orientation to door, pawing/mouthing apparatus, feeder interaction, sniffing ground, shake off, lip lick, lay, sit and whining. All behavioural dependent variables (DVs) were modelled using Generalized Linear Mixed Models (GLMMs) with the glmmTMB package (Version 1.1.13) in R (Version 4.3.1) to account for the non-normal distribution of behavioural data and the repeated-measures design. Data manipulation and visualization were conducted using the tidyverse suite (Version 2.0.0), specifically dplyr (Version 1.1.4) and ggplot2 (Version 4.0.1). Post-hoc comparisons and marginal means were calculated using the emmeans package (Version 1.11.2-8). Each model included Dog ID as a random intercept to account for non-independence of observations within individual subjects. Models included condition (Breakfast vs No Breakfast), time of day (minutes since 9:00 AM), and the number of experimental days since the dog started training as fixed effects, with interactions between Condition and each temporal predictor. Continuous predictors were z-scaled prior to modelling. Dog identity was included as a random intercept to account for repeated measures. A dispersion model including log(session length) was specified to account for variability related to observation duration.

Duration behaviours (e.g. sit, lay, tail positions, whining) were analysed using beta generalised linear mixed-effects models (GLMMs). Because the beta distribution cannot process values of exactly 0 or 1, proportions were adjusted using the Smithson and Verkuilen (2006) transformation. Models were fitted using the glmmTMB package (Version 1.1.13) in R, with a logit link function and a precision model (dispformula) conditioned on the log of session duration to account for heteroscedasticity. Model predictions were generated marginally and back-transformed to the response scale for interpretation. For each behaviour, duration was expressed as a proportion of session length.

Frequency behaviours (e.g. lip licking, yawning, pawing, sniffing) were analysed using negative binomial mixed-effects models (nbinom1)

Table 2
Behaviour ethogram during scent detection task.

Behaviour	Description	Type (Duration (s)/Count)
Tail		
Tail position – high ^a	Tail is held upright, in line with topline and anything above the topline of the dog. Tail position is held for > 5 s before change is recorded.	D
Tail position – low ^a	Tail is held below topline; tip is faced outward away from the body. Any position below topline. Tail position is held for > 5 s before change is recorded.	D
Tail still ^a	Tail is still and not moving in relation to the rest of the body. Tail is immobile.	D
Tail wag ^a	Tail sweeps laterally with the body from side to side, at slow or fast speed.	D
Vocalise		
Bark	Short sharp vocalisation.	D
Whine ^a	Drawn out noise or whimpers.	D
Mouth/face		
Pant	Mouth open, tongue showing inside or outside the jawline.	C
Lip lick ^a	Tongue flicks up over or across nose for 1 s or less. Measurement excluded during interaction within 30 cm of a human, and within 5 s of eating a treat.	C
Yawn ^a	Opening the mouth and inhaling and exhaling air, tongue curls.	C
Mouth Object ^a	Dog opens mouth and puts teeth on an object. Jaws may bite into object or be closed without pressure on an object.	C
Body posture		
Sit ^a	Dog is resting on haunches.	D
Lay down – head up (Prone) ^a	Dog is laying with all four limbs and abdomen flat to ground and head upright or alert.	D
Lay down – head down ^a	Dog is laying with all four limbs and abdomen flat to ground, or on side, with chin resting on ground.	D
Shake off ^a	Dog shakes coat side to side vigorously.	C
Paw object ^a	Dog uses paw to scratch or dig at object.	C
Sniff ground ^a	Dogs nose sweeps downward to ground momentarily, still moving or pausing for less than one second. Not measured at base of feeder during acquisition of treat.	C
Body stretch	Dog lowers chest and front legs to ground, with hind end upright.	C
Scratch self / Groom	Dog scratches at neck, usually sitting with hindquarters on ground and one leg scratching fur around neck or shoulders, or self-grooms by nibbling at own fur.	C
Ears		
Ears forward	Ears are facing forward towards bridge of nose sustained for > 2 s.	C
Ears back	Ears turned backwards sustained for > 2 s.	C
Orientation ^a	Dog is orientated towards stimuli for > 3 s; human, door	D
Out of sight	Dog is out of sight, not in view of the camera or over door threshold/out of the room.	D
Feeder interaction ^a	Interaction with feeder: paw, lick, sniff, stare for longer than 4 s.	C

^a Behaviours included in final analyses.

to account for overdispersion. Models included the same fixed effects structure as duration analyses and incorporated log(session length) as an offset, allowing effects to be interpreted as event rates. For figures, predicted values were back-transformed and expressed as events per minute to improve interpretability.

An a-priori simulation-based power analysis was conducted to determine if the sample size and number of condition repetitions was sufficient to detect a small effect (.2). This was conducted in R (Version 4.3.1) using the lme4 package (Version 1.1–37). Applying a Bonferroni

correction ($\alpha = .0036$), and assuming 6 subjects were exposed to each condition 20 times, with 500 iterations of the simulation, a power estimate of 81% was produced.

3. Results

Statistically significant effects will be described below; all other effects were non-significant. The statistical output and figures associated with all analyses can be found in the [supplementary material](#) (See S4). Data from a total of 6 dogs that participated in the study were used in the final analysis, with data from a total of 491 videos analysed. The mean session length was 431.33 s (SD = 197.26), with video durations ranging from 189 to 1589 seconds.

3.1. General findings on overall behaviour within scent sessions and across study days

Across all sessions, dogs spent the greatest proportion of time with the tail held low (85% of the session time), followed by tail still (73%) and tail wagging (21%) (Fig. 2a; see S3 for specific values). Postural behaviours such as lying and sitting occupied a relatively small proportion of the session (<6% on average), while environmental interactions (oriented to door) were infrequent. Vocalisations were rare, with whining comprising approximately 2 – 3% of session time across conditions. Sample sizes (113 sessions) varied for whining compared to all other behaviours due to the absence of the ability to record whining in sessions prior to September. Several behaviours associated with stress (yawning, lip lick, sniff ground and shake off) were also rare.

Frequency variables were analysed according to the number of occurrences of each behaviour per minute in each session. Across conditions, lip licking and ground sniffing were the most frequently observed behaviours occurring at mean rates of 0.34 and 0.33 events per minute, respectively (See S3). Environmental interactions such as times orienting to the door, mouthing objects and pawing the scent apparatus occurred at lower but consistent rates, with the latter two being carried out mostly by one individual (Fig. 2).

3.1.1. Inferential findings for overall behaviours observed within scent sessions and across study days

There was a significant change in whining across the recorded study days (estimate = -0.26 , $z = -2.81$, $p = .005$; Fig. 3a), with whining decreasing slightly over time within the sessions for which audio was available. Unlike all other behaviours, early sessions for whining were not recorded, so these patterns describe only the measurable sessions.

Frequency of ground sniffing showed a strong effect for time of day, with dogs sniffing more in the sessions earlier in the morning than later in the morning (estimate = -0.37 , $z = -5.65$, $p < .001$; Fig. 3b). Frequency of lip licking significantly increased over the course of the study (estimate = 0.17 , $z = 3.38$, $p < .001$; Fig. 3c). Lip licking also showed a strong effect for time of day, with dogs lip licking less as the day progressed (estimate = -0.25 , $z = -4.15$, $p < .001$; Fig. 3d).

All other analyses of general changes in behaviour associated with time of day or the study day produced non-significant results (see S5).

3.1.2. Effect of meal on behaviour

No statistically significant breakfast condition effects were observed for any of the duration measures. Breakfast did not significantly alter how long dogs spent in postures, tail states, interacting with their environment, nor how these durations evolved within sessions or across days since starting the study.

The frequency of whining was affected by breakfast condition. Dogs that had not eaten breakfast whined significantly more than those that had eaten (estimate = -0.58 , $z = -2.51$, $p = .01$; Fig. 4a). The effect of breakfast on whining also interacted with the number of days that the dog was in the study (estimate = 0.19 , $z = -2.99$, $p = .003$; Fig. 4b), with whining after breakfast declining more steeply across study days.

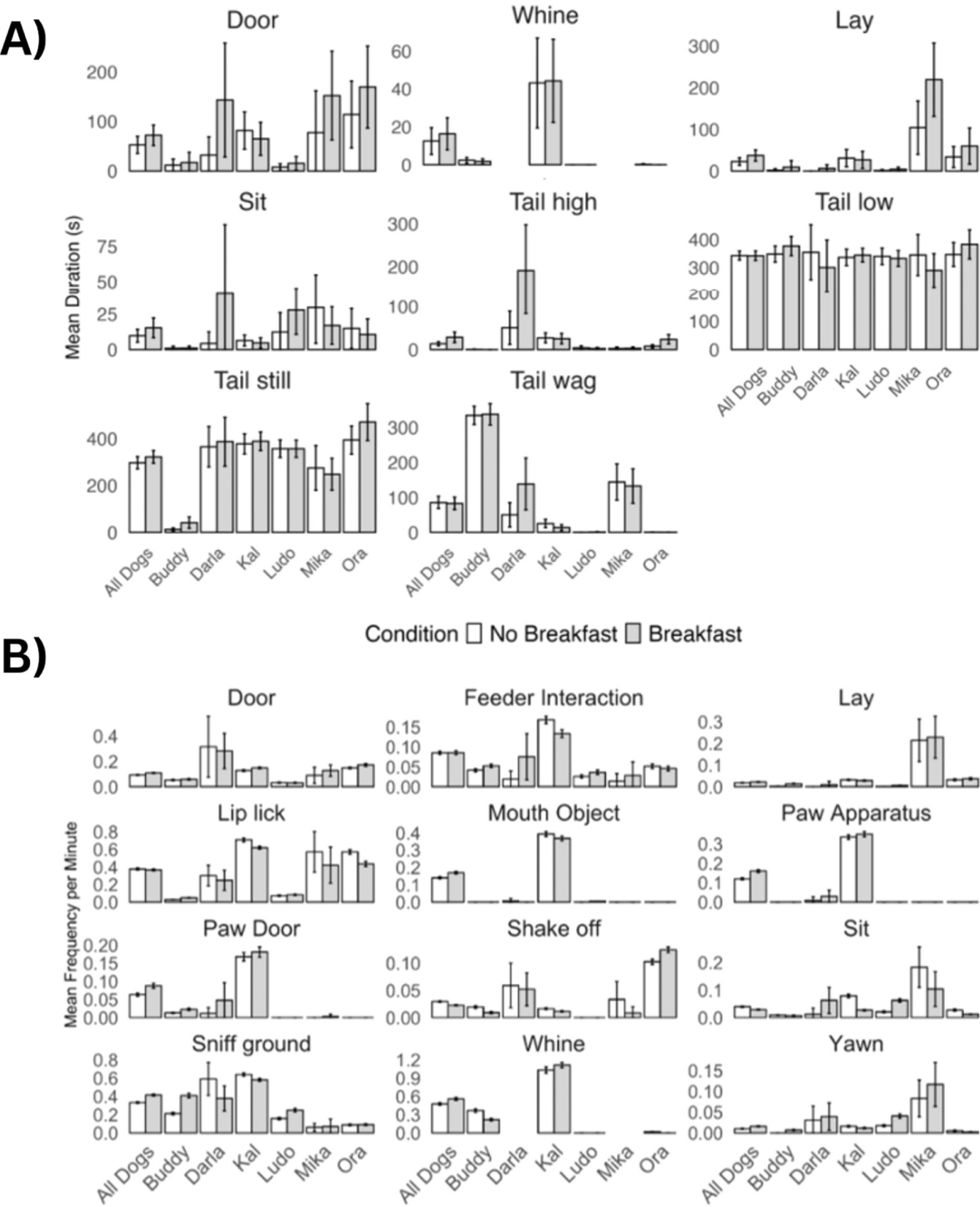


Fig. 2. Observed means for (A) duration (in seconds) of behaviours in the Breakfast and No Breakfast conditions and (B) frequency of behaviour (per minute) for individual dogs. Error bars represent 95% confidence intervals. See Table 2 for behaviour definitions. Whine was recorded for 113 sessions. Note that y-axis scales differ across measures.

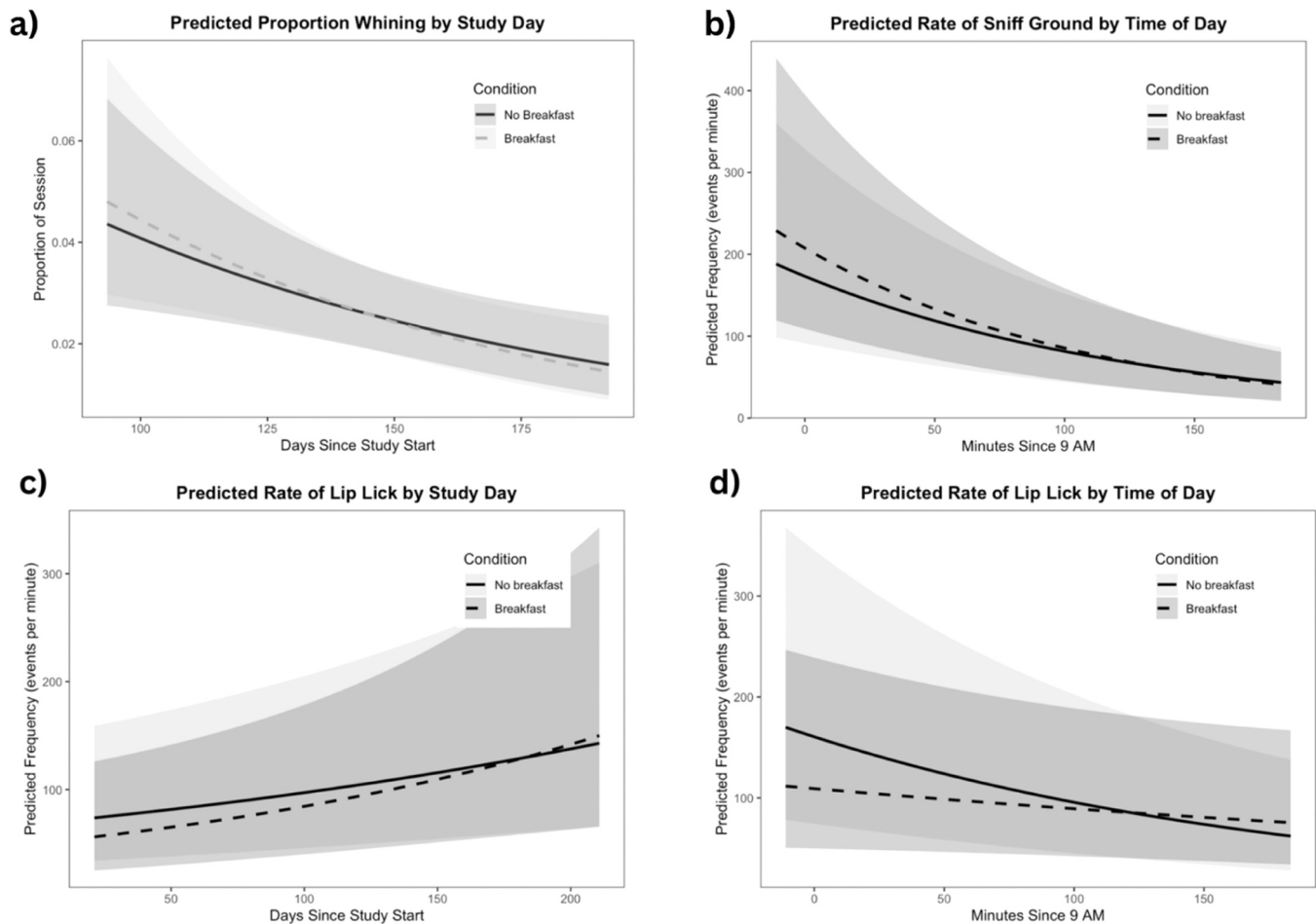


Fig. 3. Model-predicted behavioural responses (proportions and rates per minute), showing marginal effects of study duration and time of day with 95% confidence intervals. Panel (a): Represents duration-based behaviour (Whining). Panels (b), (c), and (d): Frequency-based (events per minute) results for Sniff Ground and Lip Lick by study day and time of day. Solid lines (No Breakfast) and dashed lines (Breakfast) represent model-predicted means. Shaded ribbons indicate the 95% Confidence Intervals (CIs). All predictions are back-transformed from the link scale (logit for Beta, log for counts) to the original response scale for interpretability.

There was a significant interaction in the influence of breakfast condition and time of day on feeder interactions. In the breakfast condition, dogs interacted with the feeder less over time than in the no breakfast condition but interacted with it for longer earlier in the day than in the no breakfast condition before showing a steeper decline in their interaction with it (estimate = -0.42 , $z = -2.40$, $p = .016$; Fig. 4c). Dogs in the breakfast condition also decreased pawing the scent apparatus over days since training started (estimate = -0.57 , $z = -2.84$; $p = .005$; Fig. 4d). The dogs pawed the apparatus infrequently, resulting in predicted rates close to zero across the day and study period, with wide confidence intervals reflecting uncertainty associated with rare events.

4. Discussion

The aim of the study was to examine overall behaviour patterns indicative of stress or frustration observed during a laboratory-based scent detection task and whether frustration-related behaviour changes as a function of having had breakfast prior to the task. Across sessions, dogs in this scent detection study, which was carried out in a laboratory setting using an automated scent apparatus and minimal human interactions, displayed relatively consistent postures, with low and still tail positions the most commonly observed forms of tail carriage. There was high individual variation across dogs in the frequency and duration of most recorded behaviours. Time of day significantly influenced some observed behavioural patterns. Both lip licking and

ground sniffing were recorded at higher frequencies during the dogs' initial sessions, earlier in the day. Additionally, the frequency of lip licking showed a steady increase over the subsequent days following initiation, while whining consistently decreased throughout the duration of the audio recorded videos in the study. There was evidence for low levels of frustration-related behaviours in some dogs during the no breakfast condition. An increase in whining frequency was observed in two of the six dogs in the no breakfast condition. A significant interaction between condition and days since study onset indicated that whining frequency decreased more sharply over time when dogs received breakfast while, in the fasted state, dogs showed a more gradual decline. Moreover, when in the breakfast condition, dogs engaged less with the feeder over successive days, whereas dogs without breakfast exhibited a higher incidence of pawing at the scent apparatus as the study progressed.

4.1. Overall behaviour patterns

In the current study, dogs spent most of the session time with the tail held low ($\approx 85\%$) or still (73%), whereas tail wagging occurred infrequently (21% ; largely driven by a single individual). Movement of the tail can signify arousal states and may modify valence in communication, dependent on speed. According to Leonetti et al. (2024), tails are held high to convey various signals, such as alertness or a desire to create space; while a lowered tail may indicate fear, anxiety, or alternatively be maintained in a relaxed, neutral position, suggesting the low and still

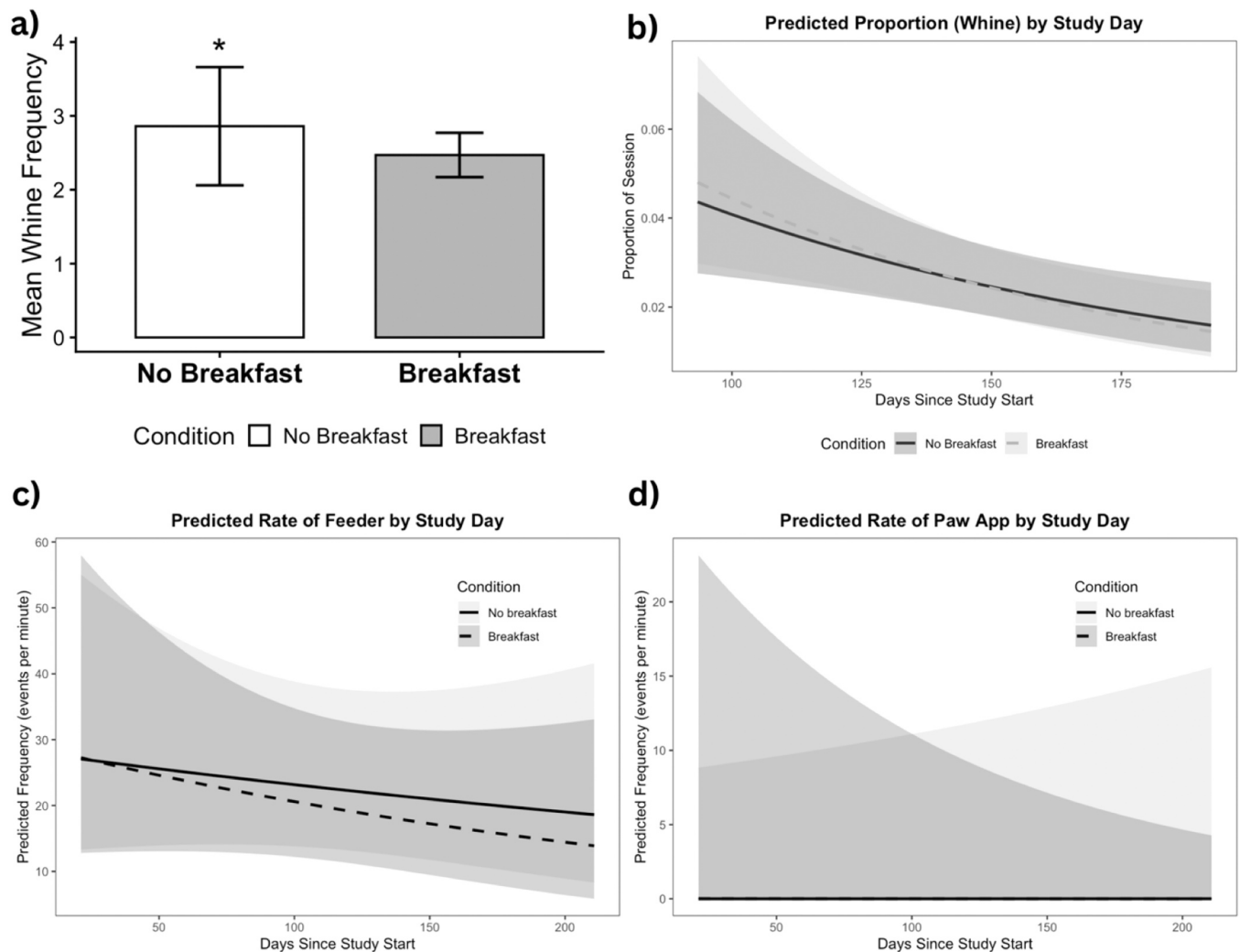


Fig. 4. Comparison of mean whine frequency between conditions (a) and model-predicted behavioural trends over study duration (b, c, d) with 95% confidence intervals. Panel (b) shows duration-based proportion of whining; panel (c) and (d) show frequency behaviour (events per minute) for Feeder interaction and Pawing the scent apparatus. Solid lines (No Breakfast) and dashed lines (Breakfast) represent model-predicted means. Shaded ribbons indicate the 95% Confidence Intervals (CIs).

tail observed throughout the sessions may be indicative of lower arousal. In contrast to the present findings, dogs show elevated tail posture and wagging during scent work involving a handler, in conjunction with increased heart rate, suggesting heightened arousal in more dynamic, handler-involved contexts (Fountain et al., 2026). Differences between these findings may also reflect variation in task demands, physical activity, and the extent of human–dog interaction, which may be more pronounced in field or class environments than in laboratory settings. In the present study, human interaction was deliberately limited.

A recent study assessed the difference in body language and search behaviour of dogs undertaking a line-up scent detection task using odorants exhibiting different diffusivity properties (Mejia et al., 2024). Results showed trends toward increased focus and orientation to the handler with stronger odours, along with more lip licking and tail wagging, but no differences in stress-related behaviours. Possible frustration-related behaviours in our study were primarily linked to time of day or changes over the study period, and less influenced by breakfast before the task. In the current study, dogs showed higher rates of lip licking earlier in the day, but also increased the frequency over the course of the study. Lip licking has been associated with both positive and negative anticipation, as well as general arousal and appeasement gesture indicative of acute stress in uncertain situations (Albuquerque et al., 2018; Caeiro et al., 2017; Pedretti et al., 2022). Lip licking may

also be linked to consumptive behaviour, occurring before or after food rewards, or it may increase during scent detection exercises to facilitate sampling via air or nasal licking and engagement of the vomeronasal organ, or moistening of the rhinarium to enhance contact with odour particles (Jenkins et al., 2018; Jezierski et al., 2008).

Similarly, brief ground sniffing, characterised by momentary lowering of the nose to the floor, has been described as a displacement or stress-related behaviour in social contexts and may function as a communicative signal to audiences (Kuhne et al., 2014; Pedretti et al., 2022; Rugaas, 2006). In the present study, ground sniffing occurred more frequently earlier in the day, particularly during the first sessions. As dogs were tested in isolation, without immediate social interaction, the behaviour may have reflected exploratory investigation of the environment rather than communicative signaling, such as detecting residual odours from previous dogs. These previous findings indicate this behaviour is complex, potentially serving multiple functions, including as a coping or displacement strategy, a way to engage with an odour of interest, or to clear the nose during detection tasks by smelling another odour. Therefore, whether the ground sniffing or lip licking observed in the present study was frustration-related is unclear.

Several of the stress-related behaviours (body stretch, panting, self-grooming) included in the ethogram were dropped from analysis because they were so rare. Participation in laboratory-based scent

activities does not appear to produce stress-related behaviours in companion dogs, that remain engaged in the task even without a handler present. Scent work is known to foster positive affective states in dogs (Duranton and Horowitz, 2019; Sobol and Dowling-Guyer, 2026). Consistent with this perspective, our results indicated low levels of frustration-related behaviours and lack of stress behaviours in a laboratory-based scent task.

4.2. Breakfast effect

Breakfast had minimal influence on either the duration or frequency of behaviours, with the scent task eliciting consistent patterns across conditions. Our hypothesis that frustration-related behaviours would increase in the no breakfast condition was supported to some extent. Whining frequency increased significantly in the no breakfast condition for two of the six dogs. Whining is more likely when food is withheld in the presence of a human (Pedretti et al., 2024) and has also been observed in lower arousal states (Flint et al., 2024). In addition to changes in whining, when dogs were in the no-breakfast condition, they showed greater engagement with the feeder earlier in the day than the breakfast condition dogs. Similarly, in the no-breakfast condition, pawing at the scent apparatus declined across study days. This distinction suggests that feeder engagement was influenced by time-of-day hunger effects, whereas pawing declined as dogs became more familiar with the task. Together, these patterns suggest that frustration-related behaviours may become more pronounced when experiencing hunger, as evidenced by heightened vocalisation and increased focus on stimuli associated with food. Additionally, increased engagement with the feeder by dogs in the no breakfast condition may reflect heightened motivational effects on tracking and responses to reward-related cues, as greater incentive value of food rewards has been shown to influence dogs' engagement in problem-solving tasks (Cook et al., 2016). These findings are broadly consistent with the rodent literature demonstrating that motivational state can influence responses to frustrative nonreinforcement (Capaldi and Hovancik, 1973; Green et al., 2026). Studies in rats have shown that greater food deprivation can increase the intensity of behavioural responses following the unexpected omission of an appetitive reinforcer. Although these paradigms differ from the present study, they suggest that hunger can modulate behavioural responses when access to an expected reinforcer is prevented or omitted.

Hunger can influence learning and attention, and delayed feeding may affect dogs' performance during scent detection tasks (Chan et al., 2005; Miller and Bender, 2012). Behavioural inhibition has also been shown to reduce subsequent task persistence in dogs, indicating that motivational or metabolic state can also influence performance (Miller et al., 2015). Prior to the scent detection study described herein, from which the video footage under analysis was obtained, the influence of breakfast on scent detection performance had not been specifically addressed. One of the key findings from the analysis of the dogs' scent detection performance was that dogs produced more false alarms in the no breakfast condition (Yee et al., 2026). This raises important questions about the mechanisms underlying the mild frustration-related behaviours that were observed in the no breakfast condition for some of the dogs. One possibility is that the higher number of unreinforced (incorrect) indications in the breakfast conditions resulted in a more severe "frustration" context (defined according to reduced availability of reinforcement). The rate of reinforcement for correct responses was held constant, but due to fewer correct responses the actual rate of reinforcement would have decreased. Further research on the influence of changes in the availability of reinforcement, when reinforcement rate is held constant across conditions may help to clarify whether frustration-related behaviour is influenced by motivating operations such as satiation directly. In contrast with these findings, search and rescue dogs operating under frustration-related conditions where they could not access a toy, showed longer response latencies to indicate

target odours and a higher number of false negatives (missing/failing to indicate the target odour) (Dickinson and Feuerbacher, 2025).

4.3. Individual variation

Behavioural expression varied markedly between individual dogs and contributed to overall variability in the results. Increasing the sample size would allow more robust examination of individual differences in shaping behavioural expressions during the tasks. Importantly, this individual variability may partially explain why condition effects were observed as changes in behavioural trajectories over time rather than consistent differences at baseline. For example, one dog (Kal) consistently showed higher frequencies and durations of pawing, door-oriented behaviour, feeder interaction, and scent apparatus mouthing, along with more frequent and prolonged whining bouts. These behaviours represented an intensified response to the apparatus lever, consistent with the amplification of behaviour that can occur when expected outcomes are violated (Jakovcevic et al., 2013). Such escalation and persistence are consistent with frustration-related behaviours and suggest that condition effects may unfold over time, differing between individuals. Another consideration is impulsivity, characterised by difficulty inhibiting responses or tolerating delayed rewards, which has been identified as a measurable behavioural trait in domestic dogs (Wright et al., 2012). Higher levels of impulsivity have been reported in adolescent male dogs (Sulkama et al., 2021), which may represent one potential mechanism underlying Kal's tendency to engage in frustration-related behaviours such as whining, pawing and mouthing the apparatus, feeder and door, especially during the early learning phase. Pawing, mouthing objects, feeder engagement and orienting to the door were most prominent during earlier sessions and declined across the study period, indicating reduced behavioural intensity with repeated task exposure and learning history. For dogs exhibiting higher initial responses, this pattern may reflect increasing familiarity with the task and decreased frustration as they gained more experience.

4.4. Limitations

Canine behaviour is nuanced and highly variable between individuals, shaped in part by morphological characteristics, and often complex to interpret reliably within and between observers. Language and interpretation around frustration as a construct has also been diverse and has not reached consensus across the literature (Wilson et al., 2025). Further, interpreting canine body language is challenging because behaviours must be considered in context of the whole body and context. Selective breeding for phenotypic traits has modified aspects of canine body language, making some signals harder to interpret. In certain breeds, tail and ear positions are limited by natural carriage, tail absence, or ear cropping. Importantly, combining behavioural indicators of stress and other emotional states with physiological measures—such as heart rate, heart rate variability, and relevant neurochemical markers—can provide a more complete understanding and should be incorporated in future studies (Cobb et al., 2025). Furthermore, there is potential that human coding errors or bias may impact the measurement of behaviour observations. Camera positioning relative to the subject, as well as low interrater agreement for some behaviours also contribute as a limitation to behavioural observations. To improve measurement precision, future studies should adopt emerging technologies that quantify dynamic body movement, such as DogFACS and automated computer vision models (e.g., YOLO) (Atif et al., 2023; Martvel, Pedretti, et al., 2025; Martvel, Zamansky, et al., 2025). A recent study employing AI-assisted behavioural analysis in scent detection tasks reported 77% accuracy in distinguishing dogs at the target odour from those off-target, surpassing professional trainers' manual assessments, although accuracy for both AI and experts decreased at lower odour concentrations (Martvel, Pedretti, et al., 2025). Significant disparities remain in accuracy, precision, and

reliability of AI, such as capturing multiple nuanced behaviours at once; thus, human observers remain essential until technology and datasets improve.

Stress- and frustration-related behaviours were coded, but other exploratory actions were not, possibly underrepresenting subtle context-specific differences. For example, tail position was recorded only if held for ≥ 4 s, so brief posture changes during interaction with the scent apparatus were not captured and may be underrepresented. This measurement approach may limit detection of more subtle or short-lived changes in tail position that could differentiate responses to target versus non-target odours across individual dogs. Furthermore, excluding dogs that displayed fearful or anxious behaviours during selection may have biased the sample toward individuals less susceptible to stress-related responses in specific contexts. Another limitation was the lack of standardisation in dogs' home feeding routines, with breakfast type and quantity determined by individual caregivers. Consequently, dogs likely differed in habitual feeding schedules, caloric intake, and satiety level, which can influence motivation and task engagement. For some dogs, completing the task prior to the expected meal may have been less challenging if they routinely operated in a relatively satiated state. In addition, individual differences in exercise routines, training history, and daily lifestyle may have further contributed to variability in the dogs' physiological state and performance during the scent detection task.

5. Conclusion

The results suggest dogs show minimal levels of frustration-related behaviours during a laboratory-based scent task if they have not eaten a meal before starting the task. Overall, some dogs exhibited behaviours consistent with mild frustration (increased whining) in the no breakfast condition, but there was high individual variation across dogs. For some individuals, earlier on in the study they exhibited pawing and mouthing the scent apparatus and door, as well as persistent interaction with the feeder but these behaviours were rarely observed later in the study, suggesting that task fluency is a contributing factor. Further research is required to disentangle the effects of task context, breed characteristics, handler involvement and arousal during olfactory tasks. Incorporating heart rate assessments or other physiological parameters would allow for evaluation and comparison of physiological responses across differing scent contexts. Participation in canine citizen science projects both advances knowledge in medical detection and canine scent abilities, potentially improving operational and recreational scent detection, but also provides a stimulating experience for the dogs. The findings suggest that it may be possible to adjust the performance of dogs in a scent detection task by altering feeding times without impacting behavioural indicators of frustration, but this varies across individuals.

CRedit authorship contribution statement

Jade Fountain: Writing – review & editing, Writing – original draft, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Journie Yee:** Writing – review & editing, Methodology, Data curation. **Susan J. Hazel:** Writing – review & editing, Visualization, Supervision. **Todd J. McWhorter:** Writing – review & editing, Visualization, Supervision. **Tyler McNutt:** Writing – review & editing, Software, Methodology, Data curation. **Timothy L. Edwards:** Writing – review & editing, Visualization, Supervision, Methodology, Formal analysis, Conceptualization.

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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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.beproc.2026.105430.

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