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The value of sniffing: A scoping review of scent activities for canines

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ABSTRACT

Extensive literature exists on the performance and abilities of the canine nose when trained to detect odours and the effectiveness of dogs in their scent detection roles. However, little is known about how engaging in scent-based activities may impact the behaviour and physiology or be of benefit to dogs themselves. This is relevant as there has been rising interest in the use of recreational scent activities for companion dogs, modelled on working detection dogs, requiring dogs to search, locate and indicate on a trained odour. The purpose of this scoping review is to determine what behavioural and physiological changes occur during scent-based activities for dogs. We aimed to identify the existing scientific literature on the topic of scent-based activities for dogs, and to determine the behavioural and physiological changes occurring when dogs are exposed to environmental odours or trained to locate scents. We identified 27 studies for inclusion in this review, according to PRISMA guidelines. The 27 studies investigated responses in three populations of dogs: shelter dogs, working dogs and owned companion dogs. Studies of working dogs focused on changes in physiology and seldom on behaviour during trained search scent detection exercises, while in shelter and companion dogs, the research emphasis was on changes occurring in response to different odours introduced to the environment. Research into scent detection in working dogs currently explores many aspects of performance and sensitivity to odour. There is a notable research gap investigating the impact of participation in scent detection tasks on the behaviour and physiology and hence the welfare of dogs.

1. Introduction

Much is known about how effective dogs can be in assisting humans in detection roles due to their olfactory capabilities. Working dogs are employed to detect agricultural and invasive pests (Kane et al., 2023; Mosconi et al., 2017), threatened species (Grimm-Seyfarth et al., 2021; Kerley and Salkina, 2007), narcotics (Jezierski et al., 2014), explosives (Lorenzo et al., 2003), missing people and pets (Jinn et al., 2020), disease (Edwards et al., 2017; Pirrone and Albertini, 2017) and contraband (Kokocinska-Kusiak et al., 2021). Further, a depth of information exists in the literature on the sensitivity, performance, discrimination ability and acuity of the canine nose as a detection tool and the anatomical characteristics driving the olfactory abilities of dogs (Aviles-Rosa et al., 2023; Coli et al., 2016; Hayes et al., 2018; Malchicov, 2019; Micheletti et al., 2016). Studies have investigated improving performance of dogs, enhancing efficacy in detection based on physiological parameters and how dogs are impacted by genetics, learning, cognition and environmental conditions (Hall et al., 2021; Hall et al., 2023). Further to this, studies explored search patterns and uses of dogs as assets across industries, and how sleep, rest or housing can impact detection canines (Ferrando and Dahl, 2022; Hare and Ferrans, 2021; Moser et al., 2023; Troisi et al., 2019). In spite of the extant research into performance, little is known about how engaging in scent-based activities may impact behaviour and physiology or be of benefit to dogs themselves.

Scent-based activities (herein referred to as 'scent activities') encompass any interaction with olfactory stimuli, where a dog is either engaging in 1) scent training tasks in which they are trained to search for and indicate on an odour and receive a reinforcer (Hall et al., 2013), 2) use their nose to search for food in the environment such as scattered feeds or food puzzle mats (Khan et al., 2023), or 3) have an odour introduced to their environment as a stimulus that encourages exploration, activity or behaviour change (Gunter and Feuerbacher, 2022; Wells, 2004).

Dogs are trained to locate odours in exercises such as tracking, trailing, and search and rescue, to locate narcotics or explosives, or detect odours that indicate presence or absence of medical conditions (Hall et al., 2021). These are examples of tasks in which both working dogs and privately-owned companion dogs participate with their

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handlers. Police and military working dogs are typically handled by operational professionals, however search and rescue dogs, and conservation detection are scent tasks undertaken by both working dogs and privately-owned companion dogs whose noses are volunteered to engage in meaningful scent tasks (Decker, 2021; Rutter et al., 2021).

There has been recent growth in recreational, sport, and competition scent activities for companion dogs. The recent focus of scent work for companion dogs has included a therapeutic or enriching function. Scent work or nosework are scent-based sports modelled on working detection dogs, requiring dogs to search, locate and indicate on a trained odour, typically an essential oil, which results in a food or toy reward (Australian National Kennel Council, 2020; Duranton and Horowitz, 2019). Behaviour professionals propose that nosework and scent work, or scent activity variations such as sniff focused walks ('Sniffaris') and directed searches for food, might enhance dog welfare and provide mental stimulation (Parthasarathy, 2011; Rooney and Parr-Cortes, 2023).

Environmental enrichment involves the provision of stimuli to animals in order to facilitate species-specific behaviours (Hunt et al., 2022; Machado and Genaro, 2014; Newberry, 1995). Specifically, this may involve stimulating foraging behaviour, exploration, sensory investigation or social interaction that mimics the behaviour the species would engage in the natural environment (Clark and King, 2008). The use of enrichment can effectively mitigate stress and enhance animal well-being while under human care (Wells, 2004; Wells and Hepper, 2017). Modification of an animal's environment, through provision of sensory, social or interactive opportunities, aims to engage an animal in natural behaviours and reduce abnormal or stress related behaviour, promote problem solving and increase coping strategies or pleasurable experiences (Fernandez and Martin, 2021; Gunter and Feuerbacher, 2022; Maple and Perdue, 2013; Zentall, 2021).

Olfactory enrichment is a sensory based enrichment defined as any odour added to an animals' environment to promote investigation, exploration, or change in behaviour, with a goal of providing a positive impact on welfare (Kontaris et al., 2020). Some forms of olfactory enrichment may include herbs, spices, essential oils, animal odours such as bedding, wool, urine or faeces and scents from other animals of the same or different species (Wells and Hepper, 2017). Welfare benefits from olfactory based environmental enrichment have been explored in animals under human care in a variety of species including sea lions (Samuelson et al., 2017), felids (Ellis and Wells, 2010; Machado and Genaro, 2014; Mellen and Shepherdson, 1997; Resende et al., 2011; Skibiel et al., 2007; Wells and Egli, 2004), primates (Vaglio et al., 2021), African wild dogs (Price, 2010), wombats (Hogan et al., 2010) and Asian elephants (Holland, 2018). In zoological facilities, some positive effects of olfactory enrichment on behaviour have included increased habitat use and exploration, more natural feeding patterns and decreased stereotypies (Clark and King, 2008; Clark and Melfi, 2012; Mellen and MacPhee, 2001).

This scoping review aims to explore the uses of scent-based activities with dogs, assessing physiological and behavioural measures in studies using a component of environmental odour or trained search tasks. Although different olfactory activities range in purpose from trained detection tasks to environmental olfactory enrichment, we included all types of scent-based activities in this review. The specific objectives are to 1) present a summary of the research investigating physiological and behavioural changes in dogs as a result of scent-based activities, and 2) identify measures utilised in studies concerning scent detection or exposure to olfactory stimuli.

2. Methods

2.1. Protocol

The review protocol was developed following the Joanna Briggs Institute (JBI) guidelines for systematic scoping reviews (Arksey and O'Malley, 2005; Peters et al., 2020; Tricco et al., 2018).

2.2. Search strategy

Scent based activities were defined as any activity where a dog is: 1) engaging in scent training tasks where they are trained to search for and indicate on odours, to earn a terminal reward, 2) using their nose to search for food in the environment such as scattered feeds or food puzzle mats, or 3) having an odour introduced to their environment as a stimulus that encourages exploration, activity or behaviour change. A formal search strategy was defined in consultation with a science librarian and three electronic databases were searched (CAB Abstracts, ProQuest and Scopus), including any papers published up to November 30, 2022. Newspapers, audio and video works were excluded from the search, limiting the results to peer-reviewed articles, theses and dissertations. Next, a grey literature search was undertaken in Google and Google Scholar. Search terms common to the database search terms were used ("dog welfare scent detection odour nose work scent work") and the first 50 results were reviewed (See appendix). No additional articles were found during the grey literature search. Finally, 7 additional articles were found through snowball searching.

2.3. Study selection

Results were imported into Covidence (Veritas Health Innovation) for screening, where duplicates were removed. The first author screened titles and abstracts for inclusion. If titles and abstracts did not provide enough detail for a decision on inclusion, full texts were reviewed. Following review of the full text, articles which did not meet the pre-determined criteria for inclusion were removed. If any articles were ambiguous in criteria for inclusion, they were discussed by the full review team. Full text reviews were carried out to further determine suitability for inclusion.

Inclusion criteria consisted of the following:

- peer reviewed articles with primary research, theses or dissertations (no book chapters, review articles or conference proceedings);
- full text was published in English;
- subjects were limited to domestic dogs (*Canis familiaris*);
- the study contained either an observational or physiological based assessment and assessed a change that impacted welfare;
- the article was related to the effect of odour;
- there was no geographical limitation on study publication.

Articles were excluded if the research focused on working dog performance, acuity, or scent discrimination measures. Studies involving pheromone treatments, scent marking (conspecific odours) or cognitive tests that involved scent in the testing, but for which scent was not the primary focus were excluded. Finally, reference lists of included studies were screened for additional peer reviewed articles suitable for inclusion.

2.4. Data extraction & synthesis

The first author collected data from articles and recorded them in a Covidence management software extraction template, pre-determined by the review team. The characteristics extracted from each article included the authors, title, journal and country of publication, followed by the following categories:

- Aims and hypotheses
- Characteristics of the population
- Description of intervention
- Observational and physiological measures taken
- Key findings

Following extraction by the first author, the whole review team checked the information for consensus.

3. Results

3.1. Selection of articles

Fig. 1 details the PRISMA-based selection process (Tricco et al., 2018). The initial search returned 1115 studies. After removal of 309 duplicates, 806 articles remained for initial screening of title and abstract. These were reduced to 31 articles based on suitability to criteria within the title and abstract. A further four studies were added from reference list screening which were not picked up in the database search. Next, articles were screened for suitability by reviewing the full text. If any article was unclear on inclusion criteria, they were reviewed by the full review team. Articles were excluded if they were review papers or if the main focus was 1) scent acuity, where the focus is on a dogs ability to learn to detect a particular odour concentration in a training context, such as threshold of lowest detectable odour (Cournoyer et al., 2022); 2) scent performance, where studies focus on efficacy of scent detection and parameters such as ideal diet, environment, handler, training and selection of dogs (Martin et al., 2022) or 3) scent discrimination, where the focus is on a dogs' ability to discriminate a particular odour (DeChant et al., 2021). Following full text screening, there were 21 studies remaining, with two publications combined into one due to the same study being published across two papers and an additional seven studies identified from the reference lists of included studies. The final 27 studies were selected for the scoping review.

3.2. Characteristics of articles

3.2.1. Study demographics

Twenty-six articles were peer reviewed, and one thesis was included from the publication dates from 2001 – 2022 (see Table 1). Studies were from a range of countries, with the highest numbers from the USA (n = 6) and Italy (n = 5). The articles were published in various animal behaviour (13 studies), veterinary behaviour (9 studies), sensor technology (3 studies), and two physiological journals. Essential oils (n = 12) were the most common odour used in studies to assess changes in behaviour or physiology. Odour presentation was primarily in an environment without a required (trained) response (i.e., environmental; n = 12), and mostly in shelter settings (n = 9). Odour presented as part of a trained detection task (i.e., trained search) were more likely to be studies assessing working dogs (n = 11) than companion dogs (n = 2). Only two studies simulated scent detection exercises in companion dogs trained to find odours (Brugarolas et al., 2019; Duranton and Horowitz, 2019).

3.2.2. Study population

A total of 772 dogs were used across the 27 studies, with a mean of 29 and median of 19 canine participants per study, ranging from 2 – 110 participants (see Table 2). Study populations across the studies included shelter dogs, owned companion dogs and working dogs (n = 9 studies 33 %, n = 7 studies, 26 %, and n = 11 studies, 40 %, respectively). A wide range of dog breeds were included in the studies, with mixed breeds representing the most common participating dogs (n = 9). The three most common breeds included across the studies were Labradors

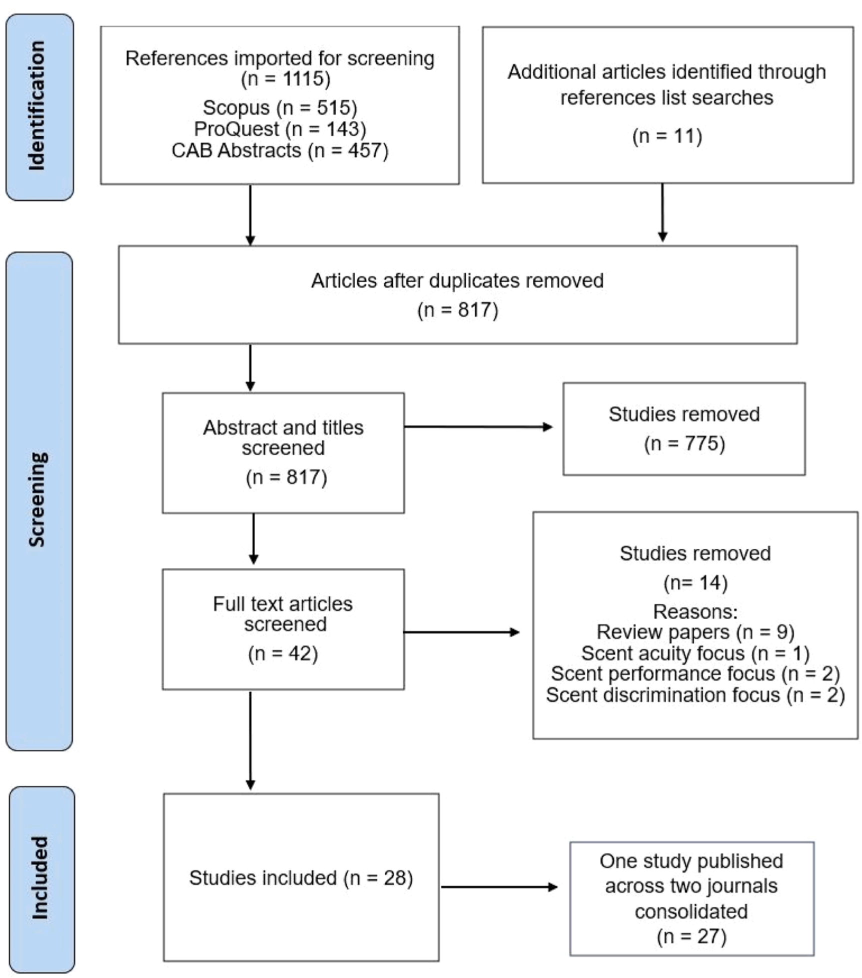

Fig. 1. PRISMA flow-chart of selection process for article inclusion.

Table 1
Odour type, presentation and aims of study across different categories of dogs in studies published between 2005 and 2022.

Reference	Population	Odour presentation	Odour type	Country	Aim
Essential oils					
Brugarolas et al. (2019)	Companion	Trained search	Anise oil	Canada	Measure physiological effects of scent work.
Wells (2006)	Companion	Environmental	Lavender oil	Ireland	Assess lavender as treatment for travel-induced excitement.
Amaya et al. (2020a & b)	Shelter	Environmental	Lavender oil	Australia	Measure physiological effects of music, DAP and lavender in shelter dogs.
Stanghellini (2019)	Shelter	Environmental	Lavender oil	Italy	Measure behavioural effects of lavender in shelter dogs.
Lopes et al. (2022)	Shelter	Environmental	3 essential oils	Brazil	Measure behaviour in shelter dogs in response to enrichment or petting.
Graham et al. (2005)	Shelter	Environmental	4 essential oils	Ireland	Measure behaviour in shelter dogs in response to essential oils.
Binks et al. (2018)	Shelter	Environmental	4 essential oils	UK	Measure behaviour in shelter dogs in response to essential oils.
Uccheddu et al. (2018)	Shelter	Environmental	9 essential oils	Belgium	Measure behaviour in shelter dogs in response to essential oils.
Haverbeke et al. (2019)	Shelter	Environmental	9 essential oils	Belgium	Measure behaviour in shelter dogs in response to essential oils.
Human odours					
Shin and Shin (2016)	Companion	Environmental	Caregiver odour	South Korea	Assess effects of owner odour on stress in absence of owner.
Baker et al. (2020)	Working	Trained search	Human remains	USA	Measure changes in core body temperature during different search phases.
Wojtaś et al. (2021)	Working	Trained search	Human remains	Poland	Measure salivary cortisol in response to search and rescue.
Ahrens et al. (2015)	Working	Trained search	Human victims	Germany	Measure physiology before and after two search conditions.
Diverio et al. (2016)	Working	Trained search	Human victims	Italy	Measure physiology and behaviour in avalanche military dogs.
Lopedote et al. (2020)	Working	Trained search	Human victims	Italy	Measure physiology before and after 3 different search and rescue types.
Mazin et al. (2001)	Working	Trained search	Human victims	USA	Measure electrolyte replacement across two search conditions.
Ohno et al. (2022)	Working	Trained search	Human victims	Japan	Measure ECG and estimate emotional labels during a search.
Rovina et al. (2008)	Working	Trained search	Human victims	Spain	Measure physiology before and after 20-minute search.
Spoo et al. (2015)	Working	Trained search	Human victims	USA	Measure physiology before and after 4-hour search.
Foster et al. (2022)	Working	Trained search	Handler scent dummy toy	USA	Measure physiological changes using body & remote sensors during search.
Animal Scents					
Samuel et al. (2020)	Companion	Environmental	Bear, lynx & beaver scat	Norway	Measure reactions of dogs to scents of predators and herbivores.
Mixture of essential oils and animal scents					
Kokocińska et al. (2022)	Companion	Environmental	33 essential oils/ synthetic	Poland	Evaluate smell preference.
Murtagh et al. (2020)	Shelter	Environmental	Lavender oil & Rabbit urine	UK	Assess effects of scent in shelter dogs.
Dare (2021)	Shelter	Environmental	Lavender oil & Rabbit urine	USA	Assess effects of scent during morning cleaning in shelter dogs.
Other scents					
Carlone et al. (2018)	Companion	Environmental	Green odour	Italy	Measure effects of green odour when isolated or in a novel environment.
Duranton and Horowitz (2019)	Companion	Trained search	Food	USA	Assess effects of nose work on affective state.
Riva et al. (2012)	Working	Trained search	Drugs	Italy	Measure effects of detection training on behaviour and brain activity.

(n = 10), German shepherds (n = 8) and Malinois (n = 6). All studies assessed a range of different dog breeds except for Foster (2022), who only included two Labradors. The age of the dogs studied ranged from 2 months to 15 years old. Several studies did not list ages or sex of dogs or did not define adult and juvenile categories.

3.2.3. *Physiological measures*

Physiological measures were used in 18 publications (see Table 3). Heart rate (n = 4), cortisol (n = 5) and body temperature (n = 5) measures were the most common physiological measures. Eleven studies used a single physiological measure, and seven studies used a combination of physiological measures. Three of these studies did not use statistical testing to assess changes in physiological parameters. All seven studies that used combinations of physiological measures were working dog studies. Heart rate significantly increased in two studies (Lopedote et al., 2020; Samuel et al., 2020) and decreased in one study (Diverio et al., 2016). Saliva cortisol was used as a measure in four studies, of which one found no significant changes (Carlone et al., 2018), two showed decreases (Shin and Shin, 2016; Uccheddu et al., 2018) and one showed an increase (Wojtaś et al., 2021), although Uccheddu et al. (2018) reported significant decreases in saliva cortisol for both the lavender and the control group. Four studies observed significant changes in body temperature measures with skin temperature significantly increased in one study (Dare, 2021) gastrointestinal temperature increased in another (Baker et al., 2020), and rectal body temperature, used in two studies, decreasing in one (Diverio et al., 2016) and increasing in the other study post-search (Lopedote et al., 2020).

3.2.4. *Behavioural measures*

Seventeen studies used behavioural measures in dogs across various settings (see Table 4). Behavioural ethograms (i.e. behavioural inventories) were most likely to be used in shelter dog studies (n = 8) and only two studies assessing working dog populations used an ethogram, however one of those did not carry out statistical testing. Studies recorded significant reductions in barking or vocalisation (n = 3), high postures and panting (n = 1), and significant increases in resting (n = 3), sleeping (n = 2), grooming, high postures during searching, lower postures in the kennel, movement and activity, and barking (n = 1, across studies).

3.2.5. *Ethograms*

Ethograms were used across fourteen of the seventeen studies that included behaviour measures. The behaviours included in the ethograms have been categorised (see Table 5). The most common category of behaviours recorded in ethograms used were ‘abnormal or stress related behaviours’ (n = 11), of which this category was more likely to

Table 2
Population demographics in included studies.

Study	Scent activity	Odour type	No	Age	Sex
Shelter dogs					
Lopes 2022	Environmental	Essential oil & animal derived	8	2 months – 6 years	5 F, 3 M
Stanghellini, (2019)	Environmental	Essential oil	11	18 months - 13 years	4 F, 7 M
Binks 2018	Environmental	Essential oil	15	Unlisted	2 F, 13 M
Murtagh 2020	Environmental	Essential oil & animal derived	44	2–5 years	18 F, 26 M
Graham 2005	Environmental	Essential oil	55	6 months - 8 years	26 F, 29 M
Amaya 2020a&b	Environmental	Essential oil	60	6 months - 11 years	25 F, 35 M
Dare, (2021)	Environmental	Essential oil & animal derived	82	Various	32 F, 50 M
Haverbeke 2019	Environmental	Essential oil	23	1 – 9 years	6 F, 17 M
Uccheddu 2018	Environmental	Essential oil	110	1–10 years	Unlisted
Companion dogs					
Brugarolas 2019	Trained search	Essential oil	9	8 Adult, 1 juvenile	4 F, 5 M
Kokocińska 2022	Environmental	Essential oil & Synthetic odours	14	1 – 4 years	10 F, 4 M
Carlone 2018	Environmental	Synthetic odour	16	20 months - 6 years	13 F, 3 M
Duranton and Horowitz, (2019)	Trained search	Food based	20	Unlisted	10 F, 10 M
Shin and Shin, (2016)	Environmental	Human odour	28	1–12 years	18 F, 10 M
Wells, (2006)	Environmental	Essential oil	32	6 months - 7 years	17 F, 15 M
Samuel 2020[a]	Environmental	Animal derived	82	4 months - 15 years	35 F, 47 M
Working dogs (Detection)					
Foster 2022	Trained search	Human odour	2	4–8 years	2 M
Ohno 2022	Trained search	Human odour	2	No age provided	1 F, 1 M
Baker 2020	Trained search	Human odour	8	1–8 years	3 F, 5 M
Lopedote 2020	Trained search	Human odour	9	6 months - 8 years	6 F, 3 M
Rovina 2008	Trained search	Human odour	9	2 – 7 years	5 F, 4 M
Ahrens 2005	Trained search	Human odour	16	1 – 11 years	Unlisted
Diverio 2016	Trained search	Human odour	17	1–8 years	2 F, 15 M
Spoo 2015	Trained search	Human odour	19	2 – 9 years	8 F, 11 M
Mazin 2001	Trained search	Human odour	20	11 months – 11 years	9 F, 11 M
Riva 2012	Trained search	Narcotics	20	1–2 years	9 F, 11 M
Wojtaś 2021	Trained search	Human odour	41	2–12 years	11 F, 30 M

[a] A combination of companion and hunting dogs were included in participants

include body shake (n = 8), lip or nose lick (n = 8), yawn (n = 6) and paw lift (n = 5). Of the nine studies that recorded vocalisations as a measure, four studies used vocalisation to include a combination of sounds, while five studies specified between different types of vocalisations.

4. Discussion

The aim of this scoping review was to determine the physiological and behavioural changes that occur in dogs engaging in scent-based activities. A total of twenty-seven studies were included in the review and investigated responses in three populations of dogs, including shelter dogs, working dogs and owned companion dogs. Studies of working dogs focused on changes in physiology and behaviour during trained search scent detection exercises, while in shelter and companion dogs, the research emphasis was on changes occurring in response to different odours introduced to the environment. Physiological and behavioural measures differed between working versus shelter and companion dogs.

4.1. *Scent detection*

Tasks in which dogs are trained to search for and indicate the location of an odour for a terminal reward are referred to as scent detection tasks. Thirteen studies focused on changes in behaviour and physiology in relation to a trained search exercise, with 11 out of 13 studies involving working dogs. There were significant increases in core body and rectal temperatures recorded in post-search measures for two studies (Baker et al., 2020; Lopedote et al., 2020), and another reported a reduction in body temperature to baseline occurring at two hours post-search (Diverio et al., 2016). An increase in body temperature during searches may be a welfare risk at high temperatures (Robbins et al., 2017). Scent detection in working dog studies primarily measured physiological responses with only three studies that included behaviour measures (Diverio et al., 2016; Ohno et al., 2022; Riva et al., 2012) using frequency and duration of observed behaviours and the Svartberg Test, a standardised behaviour test. Ohno et al. (2022) did not perform statistical testing. Only two studies investigated training companion dogs in scent detection tasks (Brugarolas et al., 2019; Duranton and Horowitz, 2019). Duranton and Horowitz (2019) reported participation in nose work classes increased optimism in companion dogs trained to search for food using a cognitive bias test but did not measure any physiological parameters while Brugarolas et al. (2019) measured physiological changes (heart rate and heart rate variability) but no behavioural changes. In Brugarolas et al. (2019), heart rate increased during sniffing tasks and the highest heart rate was recorded at the beginning of the search and at the end of the search. Excitement in starting the search and the excitement associated with receiving the reward at the terminal end of the behaviour may explain the fluctuations in heart rate at the start and finish of the search.

4.1.1. *Environmental scents*

Fourteen studies used environmental scents with odours introduced to the environment and measured behaviour or physiological changes in the dogs. Observed behaviour changes included reduced levels of barking and increased time spent both sleeping and resting (Binks et al., 2018; Graham et al., 2005; Wells, 2006). One study using a cognitive bias test reported increased optimism after exposure to either a blend of nine scents (oils of litsea, cypress, sweet orange, geranium, lavender, ylang-ylang, juniper, rockrose and bay leaf) or listea oil as a single odour (Uccheddu et al., 2018). Similarly, a reduction in high posture, associated with lower stress was reported after the same blend of nine scents was used in a different study of dogs (Haverbeke et al., 2019). Lavender was the essential oil presented most, being used in three studies as the single odour (Amaya et al., 2020a; Amaya et al., 2020b; Stanghellini, 2019; Wells, 2006) and in combination with other essential oils or odours in a further seven studies (Dare, 2021; Graham et al., 2005; Haverbeke et al., 2019; Kokocinska et al., 2022; Lopes et al., 2022; Murtagh et al., 2020; Uccheddu et al., 2018). For the studies that used lavender, there was a measured increase in observed time resting and relaxed body postures such as inactivity, laying down, sitting and sleeping (Binks et al., 2018; Dare, 2021; Graham et al., 2005; Wells,

Table 3
Summary of type of physiological measures and outcomes in included studies in shelter, companion and working dogs in response to environmental odour or trained scent detection tasks. ↑ Increase, ↓ decrease.

Author & year	Population	Odour presentation	Odour type	Physiological measure	Outcomes
Single measure					
Brugarolas 2019	Companion	Trained search	Essential oil	Heart rate, heart rate variability	* **No statistical tests were performed.
Samuel 2020	Companion	Environmental	Animal derived	Heart rate	↑ Heart rate in response to bear scats & lynx scats ($p < 0.001$).
Amaya 2020a	Shelter	Environmental	Essential oil	Heart rate variability	No significant difference with the lavender condition.
Ohno 2022	Working	Trained search	Human odour	Heart rate, heart rate variability	* **No statistical tests were performed.
Dare, (2021)	Shelter	Environmental	Essential oil & animal derived	Body temperature (Skin)	↑ Skin temperature when owner surrendered dogs exposed to scent enrichment ($p = 0.001$).
Baker 2020	Working	Trained search	Human odour	Body temperature (Gastrointestinal)	↑ body temperature in working phase ($p < 0.0001$). ↑ body temperature during post work phase ($p < 0.0001$).
Carlone 2018	Companion	Environmental	Synthetic odour	Saliva cortisol	No significant differences in salivary cortisol levels.
Shin 2016	Companion	Environmental	Human odour	Saliva cortisol	↓ Saliva cortisol pre-test to post-test for the group with owner scent treatment. ($p < 0.05$). ↓ Saliva cortisol between first test to the third test during separation. ($p < 0.005$).
Uccheddu 2018	Shelter	Environmental	Essential oil	Saliva cortisol	↓ Saliva cortisol in lavender ($p = 0.039$) and control ($p = 0.031$).
Wojtaś 2021	Working	Trained search	Human odour	Saliva cortisol	↑ Saliva cortisol in male dogs in open field search setting ($p = 0.005$).
Riva 2012[a]	Working	Trained search	Human odour	Blood neurotransmitters	↓ 5-HT serotonin post training ($p < 0.01$).
Combination measure					
Ahrens 2005	Working	Trained search	Human odour	Blood chemistry, blood cortisol, body temperature (type not specified)	↑ Cortisol after winter search at 60 minutes post ($p < 0.05$).
Diverio 2016	Working	Trained search	Human odour	Blood cortisol, heart rate, body temperature (Rectal)	↓ Heart rate ($p = 0.004$) for dogs searching with their head up right. ↓ Body temperature back to normal 2 hours post-test ($p = 0.000$). ↓ Blood cortisol between pre-test and beginning of search, ↓ post search ($p = 0.003$).
Lopedote 2020	Working	Trained search	Human odour	Respiratory rate, heart rate, body temperature (Rectal)	↑ Heart rate after searches on the field and in rubble ($p < 0.05$). ↑ Rectal temperature – post search following rubble trial ($p = 0.02$).
Mazin 2001	Working	Trained search	Human odour	Blood chemistry, pulse rate, respiration rate, blood gas, body temperature (type not stated)	↓ Sodium post winter search (electrolyte group; $p < 0.05$) ↑ Chloride post winter search (electrolyte group; $p < 0.05$). ↑ Glucose post summer search (electrolyte group; $p < 0.05$).
Rovina 2008	Working	Trained search	Human odour	Heart rate, respiratory rate, blood chemistry, body temperature (Rectal)	↑ Heart rate between baseline - post search; baseline to recovery 5, 15, 30 mins ($p < 0.05$). ↓ Heart rate between activity and 30 mins recovery ($p < 0.05$). ↑ Respiratory rate baseline - search; search - 5 mins post search; baseline to 5, 15, 30 mins post search ($p < 0.05$). ↑ Rectal temp baseline – search; baseline – 5, 15, 30 mins post search ($p < 0.05$). ↑ Serum creatinine, CK baseline – search; baseline – 5, 15, 30 mins post search ($p < 0.05$). ↓ Na baseline – search; baseline – 5, 15 mins post ($p < 0.05$). ↓ Cortisol from baseline to 30 mins post, and activity to 30 mins post ($p < 0.05$).
Spoo 2015	Working	Trained search	Human odour	Blood chemistry, blood gas, body temperature (Rectal)	↓ Na ($p < 0.025$), P ($p < 0.025$), Mg ($p < 0.025$) post search. ↑ Serum creatinine ($p < 0.025$), CK ($p < 0.025$), AST ($p < 0.025$) post search. ↑ Cortisol post search compared to baseline, and compared to control dogs ($p < 0.01$).
Foster 2022	Working	Trained search	Human odour	Heart rate, heart rate variability, body temperature (Skin)	* **No statistical tests were performed.

[a] Neurotransmitter levels evaluated were adrenaline, noradrenaline, L-3,4-dihydroxyphenylalanine, homovanillic acid (HVA), 3-methoxy-4-hydroxyphenylglycol acid (MHPG), 5-hydroxyindole acetic acid (5-HIAA), and 5-hydroxytryptamine (5-HT).

Table 4
Summary type of behavioural measures and outcomes in included studies in shelter, companion and working dogs in response to environmental odour or trained scent detection tasks. ↑ increase, ↓ decrease.

Author/ Behaviour measure	Population	Odour presentation	Odour type	Outcomes
Ethogram				
Wells, (2006)	Companion	Environmental	Essential oils	↑ time resting and sitting, ↓ moving and vocalising than the control dogs with no lavender ($p < 0.001$).
Amaya 2020b	Shelter	Environmental	Essential oils	↓ panting if exposed to lavender ($p = 0.04$). ↑ grooming overnight in lavender treatment ($p = 0.01$).
Binks 2018	Shelter	Environmental	Essential oils	↓ levels of barking and movement in all four types of odours compared to the controls ($p < 0.001$). ↑ time resting during exposure to coconut, ginger, valerian, and vanilla ($p < 0.001$). ↑ time sleeping during exposure to coconut ($p < 0.05$) and ginger ($p < 0.01$).
Dare, (2021)	Shelter	Environmental	Essential oils & rabbit urine	↑ relaxed body postures with scent enrichment (lavender and rabbit urine; $p = 0.043$). ↑ body posture lower with lavender ($p = 0.017$).
Graham 2005	Shelter	Environmental	Essential oils	↑ time standing and moving during peppermint and rosemary conditions ($p < 0.05$). ↑ resting when exposed to lavender or chamomile ($p < 0.05$). ↓ less time barking when exposed to lavender or chamomile ($p < 0.05$). ↑ barking time during exposure to peppermint ($p < 0.05$).
Lopes 2022	Shelter	Environmental	Essential oils & fish oil	No significant findings relating to enrichment items.
Murtagh 2020	Shelter	Environmental	Essential oil & rabbit urine	↑ likelihood of play with scented toys ($p = 0.001$). ↓ stress related behaviours observed when toys present whether scented or unscented ($p = 0.001$).
Stanghellini, (2019)	Shelter	Environmental	Essential oils	↑ observed stress behaviours, (for behaviour list, see Table 5) in control group over time ($p = 0.05$).
Haverbeke 2019	Shelter	Environmental	Essential oils	↓ high posture baseline to week 8 ($p < 0.0001$) and between week 1 and 8 ($p < 0.0001$) for Group 1. ↓ high posture between baseline and week 8 ($p < 0.0007$) and week 1 and 8 ($p = 0.0368$) for Group 2.
Diverio 2016	Working	Trained search	Human odour	No significant relationships for duration or frequency of behaviours.
Ohno 2022	Working	Trained search	Human odour	* **No statistical tests were performed.
Cognitive bias test & ethogram				
Uccheddu 2018	Shelter	Environmental	Essential oils	↓ latency to reach ambiguous bowl after exposure to blend of 9 oils ($p = 0.039$) and litsea oil ($p = 0.078$). ↑ higher postures with bay leaf oil condition ($p = 0.047$).
Duranton and Horowitz, (2019)	Companion	Trained search	Food	↓ latency to reach ambiguous bowl following nose work classes ($p = <0.01$).
Ainsworth Strange Situation Test & ethogram				
Carlone 2018	Companion	Environmental	Green odour	↓ proximity to caregiver in odour condition ($p = 0.045$). ↑ sitting and standing behaviour in odour condition ($p = 0.030$; $p = 0.037$). ↑ following caregivers post-return in non-odour condition ($p = 0.007$).
Odour time/proximity				
Samuel 2020	Companion	Environmental	Animal based	↓ less time spent in proximity of bear and lynx scats ($p < 0.001$).
Kokocińska 2022	Companion	Environmental	Essential oils/Synthetic	↑ proximity to odour of interest ($p < 0.0001$).
Svartberg Test (2005)				
Riva 2012	Working	Trained search	Human odour	↓ post training scores for stranger reaction ($p < 0.05$), cooperation ($p < 0.05$), reaction to touch ($p < 0.01$).

2006). Both in humans (Atsumi and Tonosaki, 2007) and in horses (Heitman et al., 2018), studies confirmed there was a decreased stress response after exposure to lavender. In humans, decreased measures of salivary cortisol occurred after smelling lavender (Atsumi and Tonosaki, 2007). In horses, saliva cortisol levels were lower in a lavender treatment group compared to a control, after exposure to a stressful event (Heitman et al., 2018). This is supported by Ghavami et al. (2022), in their review of the human literature, who suggest lavender significantly reduces stress reported by individuals.

However, there were no physiological changes in response to lavender in the included studies in this review. Amaya et al., (2020a) found no significant changes for measured heart rate variability in shelter dogs exposed to lavender via a diffuser over three days while Uccheddu et al., (2018) found no change in salivary cortisol in the lavender treatment group, compared to the control group. Further research is needed as none of the included studies examined the effects of differences in concentration and strength of different odours on the physiology and behaviour of dogs. Moreover, some studies included in this review assessing environmental odour offered limited opportunities for dogs to distance themselves from or to choose engagement with the introduced scents, which were often presented on bandanas or collars worn by dogs which are perhaps more restrictive than presentations on toys or via diffusers placed inside or outside of the kennel.

4.1.2. *Ethograms and behaviour measures*

Ethograms are behavioural inventories that are used to categorise observed behaviour and assess changes over time. Behaviour observations and scoring of ethograms was least likely to be used in working dog studies (1 out of 11 studies) and most often used in shelter settings (8 out of 9 studies). Listed behaviours within individual ethograms varied, with inconsistent descriptions or lack of detail impeding comparisons between studies. For example, five studies listed vocalisation as an observed behaviour, but did not describe the type of vocalisation recorded (Amaya et al., 2020b; Binks et al., 2018; Graham et al., 2005; Lopes et al., 2022; Murtagh et al., 2020), while specific vocalisations such as barking and whining were listed in other studies (Carlone et al., 2018; Diverio et al., 2016; Stanghellini et al., 2019; Uccheddu et al., 2018; Wells, 2006). Stress related behaviours as a category was

Table 5
Summary of observed behaviours used in ethograms across 20 studies in the olfactory literature. All except one study described abnormal or stress related behaviours.

Shelter	Odour presentation (Type)	General Activity	Manipulate/ Investigate Object/ Environment	Vocalisation	Inactivity	Abnormal/ Stress-related	Location/ Placement	Other
Amaya 2020 (a&b)	Environmental (Essential oil)	Pace, circle, play bounce, ground roll, spin, walk	Paw/stand bars/ door/wall, sniff ground, object play, manipulate bed/ bandana/equipment	Vocalise	Lie down - head up/ down, sit, stand	Body shake, yawn, pant, nose/lip lick, paw lift, body scratch	Position in kennel	Groom, tail position/ movement, drink, excretion
Binks 2018	Environmental (Essential oil)	Move	-	Vocalise	Sleep, sit, stand, rest	Stereotypy (repetitive)	Position in kennel	-
Dare, (2021)	Environmental (Essential oil & rabbit urine)	Locomotion, play bow	Dig, dig at door, approach/manipulate enrichment	-	Lay/sit relaxed, stand	Body shake, stand/ sit/laying pant, low posture, coprophagy, scanning	Stand on wall/ door	Groom
Graham 2005	Environmental (Essential oil)	Move	-	Vocalise	Sleep, sit, stand, rest	Stereotypy (repetitive)	Position in kennel	-
Haverbeke 2019	Environmental (Essential oil)	-	-	-	-	-	-	High, neutral, half low, low and very low postures
Lopes 2022	Environmental (Essential oil)	Pace, alert, walk, run	Play, dig, eat, forage, scrape body on ground, manipulate enrichment	Vocalise	Circle to lie down, stretch, sleep	Body shake, yawn, scrape, escape	-	Defecate, urinate, groom, social – positive, social - negative
Murtagh 2020	Environmental (Essential oil & rabbit urine)	Pace, wall/play bounce, tail chase, circle, explore	Interact with toy	Vocalise	Sleep, rest, inactive other, vigilant, alert	Body shake, yawn, nose/lip lick, crouch, coprophagy, paw lift, startle	-	-
Stanghellini, (2019)	Environmental (Essential oil)	-	Lick parts of the body, Scratch door	Howl, bark, yelp	-	Body shake, pant, lip lick, scratch	Orientation to door	Defaecate/ urinate
Uccheddu 2018	Environmental (Essential oil)	Pace, circle	Dig, floor lick	Bark, whine, roar, growl, yelp, teeth clap	-	Yawn, pant, lip lick, paw lift, auto groom	-	Defaecate/ urinate
Companion Dogs								
Carlone 2018	Environmental (Green odour)	Exploration, locomotion, social wag, play	-	Bark, whine	Lay, sit, stand	Body shake, yawn, nose/lip lick, salivation, tremble, auto groom, paw lift, escape	Orientation to door/owner/ stranger/chair	Social – attention seek, proximity, approach, explore, avoid, contact
Duranton and Horowitz, (2019)	Trained search (Food)	-	-	-	-	Body shake, yawn, lip lick, auto groom	-	-
Kokocińska 2022	Environmental (Essential oil & Synthetic)	Wag, jump	Licking sample	-	-	Body shake, yawn, lip lick, sneeze	-	Head position, nostril use to investigate
Wells, (2006)	Environmental (Essential oil)	Walk, jump around in car		Bark, whine, whimper	Sit, rest, stand			-
Working Dogs								
Diverio 2016	Trained search (Human odour)	Walk, run, explore head down/head up	Intensive/standard dig, play	Bark	Still head up/ down	Body shake, yawn, pant, snout/lip lick, paw lift, circle	-	-

measured in most studies that used ethograms and but were also inconsistent combinations of behaviours, such as body shake (9 of 11 studies), nose lip/ick (8 of 11 studies), yawn (8 of 11 studies) and paw lift (5 of 11 studies). However, no consensus on which behaviours to include as a valid measure of stress indicator has been reached across the literature, nor whether they are an accurate measure of eustress or distress. For example, assessments of acute stress behaviours found body shaking, nose/lip licking, paw lifts, yawning and lowered posture increased in response to a range of visual, audible and physical stimuli when dogs were startled (Beerda et al., 1997; Beerda et al., 1998). While Pastore et al. (2011) recorded higher instances of paw lifts, body shaking, head turns, trembling and urination, but not yawning or lip licks. This highlights the need for clearer consensus in ethograms across studies.

Other behavioural measures included cognitive bias testing before and after an intervention and the use of scored, standardised tests. For example, one such test was a modified version of the evaluation for working dog aptitude and behaviour reactivity designed by Svartberg (Riva et al., 2012; Svartberg, 2005) and a modified version of the Ainsworth Strange Situation Test adapted for dogs from human assessments of relationship and attachment to measure their relationship with their handler (Carlone et al., 2018).

4.1.3. Physiological measures

The majority of the working dog studies used multiple physiological measures but were less likely to use behavioural measures. The reverse was true for shelter dog studies. Physiological assessment was only used in three out of seven shelter dog studies, investigating heart rate variability, skin temperature and saliva cortisol in response to environmental odours (Amaya et al., 2020a; Dare, 2021; Uccheddu et al., 2018). In companion dogs, researchers investigated changes in saliva cortisol levels before and after separation from their caregiver when exposed to odours (Carlone et al., 2018; Shin and Shin, 2016). Shin and Shin (2016) found a reduction in salivary cortisol between baseline and post-treatment, and between the first and third tests for dogs left with articles of clothing smelling of their caregiver. However, Carlone et al. (2018) found no significant changes to salivary cortisol when dogs were exposed to green odour before separation. While salivary cortisol is a commonly used measure of short-term stress, favoured for its non-invasive collection method, it may not always offer a precise assessment of acute stressors and can fluctuate with circadian rhythm, age and sexual status, certain drugs and other environmental stressors (Chmelikova et al., 2020; Cobb et al., 2016). Without additional physiological or behavioural measures, it is difficult to characterise stress responses in these contexts, as an increase in one physiological measure is not necessarily affiliated with emotional state in these contexts (Barnett and Hemsworth, 1990; Cobb et al., Under Review). Working dog studies focused on scent detection tasks utilised heart rate and body temperature with a goal to examine optimum post-search recovery rates (Baker et al., 2020) and measures of fitness (Lopedote et al., 2020) or to improve selection strategies and training procedures (Riva et al., 2012).

Heart rate and heart rate variability has been used to validate behavioural indicators of stress. In dogs being petted by unfamiliar people, Kuhne et al. (2014) found reduced parasympathetic activity and increased appeasement behaviour in association with increased heart rate and decreased root mean square of successive heartbeat interval differences (RMSSD). Likewise, Gacsi et al. (2013) measured increased heart rate and decreased heart rate variability together with observed behavioural reactivity (growling and barking) when unfamiliar people approached dogs in a threatening way. Physiological results may be influenced by method of collection, or acute stressors within the studies, such as working dogs being transported by helicopter to the study site (Diverio et al., 2016) or confounded by excitement, exercise and exertion of the task, such as covering large distances outdoors over difficult terrain (Schneider and Slotta-Bachmayr, 2009; Wojtaś et al., 2021). Eight studies out of 27 used combinations of both physiological and behavioural measures to assess changes in dogs undertaking scent detection activities. Multiple physiological measures reduce the likelihood of misinterpretation of findings examining short term stress responses, relative to studies using single measures (Beerda et al., 1998; Cobb et al., 2021). Stress responses are complex, involving changes across the hypothalamic-pituitary-adrenal (HPA) and sympathetic-adrenal-medullary (SAM) pathways, resulting in multiple physiological responses that can be difficult to interpret (Chmelikova et al., 2020; Cobb et al., Under Review). Multifactorial combinations of measures that assess both behaviour and physiological states may provide a more detailed picture and comprehensive assessment of stress and efficacy of interventions, that more clearly reflects affective states and welfare changes (Beaulieu, 2024). Four studies using combination measures aimed to evaluate the fitness of dogs engaged in search activities, focusing on the assessment of their exercise physiology rather than on the changes that occur during scent detection tasks (Ahrens et al., 2005; Mazin et al., 2001; Rovira et al., 2008; Spoo et al., 2015).

4.1.4. Limitations

Some limitations need to be acknowledged in regard to the quality of this scoping review. While the authors made considerable efforts to include all relevant articles in the review, it is possible that certain studies may have been overlooked due to the selection of databases and search terms. All articles needed to be published in English, which means it is plausible that some pertinent literature published in other languages might not have been included in the search.

Conclusion and recommendations

Our scoping review showed that research has been done primarily with environmental odours or scent detection, but neither category has been examined in depth across settings with different populations of dogs. There is also a need for further studies to use combinations of physiological and behavioural measures to assess changes and better understand how undertaking scent-based activities or being exposed to odours is influencing the behaviour and physiology of dogs. Most included studies used either physiological or behavioural measures but not both and relied on single rather than multiple measures. This lack of research limits our understanding of the welfare implications of scent activities for dogs in any capacity. Previous research on working dogs has concentrated on their physiology and detection abilities, while studies on companion and shelter dogs have primarily utilised ethograms to evaluate welfare. There is a significant need for further investigation into how participating in scent detection tasks affects the welfare of dogs in various settings, particularly companion and shelter dogs involved in recreational scent detection.

Contributions

Jade Fountain – conception, design, data collection, data analysis, drafting article, revising article. Eduardo Fernandez – design, revising article. Todd McWhorter – revising article. Susan Hazel – conception, design, data analysis, revising article

CRediT authorship contribution statement

Todd J McWhorter: Writing – review & editing, Supervision. **Susan J Hazel:** Writing – review & editing, Supervision, Formal analysis, Conceptualization. **Jade Fountain:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Eduardo J Fernandez:** Writing – review & editing, 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

ProQuest

(TITLE(dog* OR cani*) NOT stype.exact("Newspapers" OR "Wire Feeds" OR "Historical Newspapers" OR "Audio & Video Works" OR "Historical Periodicals")) AND ((title(behaviour) OR title(enrichment) OR abstract(behav*) OR title(anxiety) OR abstract(physiol*) OR abstract("heart rate") OR abstract(treatment) OR abstract(cortisol) OR abstract("well being") OR abstract(welfare)) NOT stype.exact

("Newspapers" OR "Wire Feeds" OR "Historical Newspapers" OR "Audio & Video Works" OR "Historical Periodicals")) AND (title(scent*) OR abstract(scentwork) OR abstract(nosework) OR abstract("nose work") OR abstract("scent work") OR abstract("olfactory enrichment") OR abstract(scent) OR abstract(olfact*) OR abstract("odor") OR abstract("scent detect*"))

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Scopus

(TITLE ((dog* OR cani*))) AND (TITLE-ABS-KEY (behaviour) OR TITLE-ABS-KEY (enrichment) OR ABS (behav*) OR TITLE-ABS (anxiety) OR ABS (physiol*) OR ABS ("heart rate") OR ABS (treatment) OR ABS (wellbeing) OR ABS ("well being") OR ABS (cortisol) OR ABS (welfare)) AND (TITLE-ABS (scent*) OR ABS (scentwork) OR ABS (nosework) OR ABS ("nose work") OR ABS ("scent work") OR ABS (scent) OR ABS (olfact*) OR ABS ("olfactory enrichment") OR TITLE-ABS ("olfactory enrichment") OR TITLE-ABS ("odor") OR TITLE-ABS (sniff*) OR ABS ("scent detect*") OR TITLE-ABS ("olfactory stimulation"))

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CAB

DE = (Dogs) **AND** DE = (behaviour) OR DE = (enrichment) OR AB = (behav*) OR DE = (anxiety) OR AB = (physiol*) OR AB = (“heart rate”) OR AB = (treatment) OR AB = (wellbeing) OR AB = (“well being”) OR AB = (cortisol) OR AB = (welfare) **AND** TI = (scent) OR TI = (“scent work”) OR DE = (olfactory stimulation) OR AB = (“olfactory enrichment”) OR DE = (smell) OR AB = ("scent detect*") OR AB = (“nose work”) OR AB = (nosework) OR AB = (sniff*) OR AB = (odor) OR AB = (olfact*)

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