Dog Behavior, 2-2023, pp. 1-14 • DOI 10.4454/db.v9i3.175

Stress and behavior assessment in police dogs due to challenging situations: Differences due to training objectives

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Abstract: Police dogs have been trained to maximize their search capabilities and are required to maintain levels of intense concentration during their working time. The main aim of this study was to evaluate stress and behavior differences in police dogs due to different scenarios and distractors according to type of training: detecting narcotics or explosives. A total of 18 dogs (14 males and 4 females) were measured. 8 were trained for narcotics detection and 10 for explosives detection. In order to test the stress reaction of dogs, 3 scenarios were developed for each type of training, being differentiated by the difficulty, Scenario 1 the easiest one, Scenario 2 an intermediate-difficulty test and Scenario 3 the most challenging one. Then, these scenarios were performed a second time, including an environmental distractor: an olfactory distractor for S1 (S1D1), an auditory distractor for S2 and a visual distractor for scenario 3. The animals' stress levels were measured with eye temperature (ET), assessed with infrared thermography, and heart rate (HR). Behavior was recorded for each animal on each scenario. These parameters were then grouped in 3 behavior aggrupation's counted in 4 scores each: Attention, Effectiveness and Fear. A descriptive analysis showed higher ET means in dogs trained for explosives' detection for most of the scenarios. A General Linear Model and Tuckey post-hoc analysis for different environmental and behavioral effects, found that ET showed statistically significant differences for scenario effect with both narcotics' and explosives' trained dogs, with S2 showing the highest ET values and S1D1 the lowest, whereas, according to behavioral effects, statistically significant differences were found for attention in narcotics' trained dogs and for effectiveness in explosives' trained dogs, with score 4 showing the highest ET means for both behavioral aggrupation's. On the other hand, Mann-Whitney U Test between behavioral means, showed that, explosives' trained dogs showed higher Attention scores but lower Effectiveness scores than Narcotics' trained dogs. Finally, ET showed medium and positive statistically significant correlations with Attention in narcotics' trained dogs (0.34) and with Fear in explosives' trained dogs (0.26), HR parameter showed a medium and negative statistically significant correlation with Attention in narcotics' trained dogs (-0.31). Our results indicated that explosives' detection dogs showed more excitability, and less effectiveness behavioral signs than narcotics' detection dogs, with no differences found related to fear signs.

Key Words: Narcotic detection; explosives detection; infrared thermography; ethogram; behavioral aggrupations; heart rate.

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Introduction

The process of domestication in dog's species, have proved to be particularly beneficial to humans due to their special olfactory abilities, being able to smell objects that men do not notice (Hayes et al., 2018). This ability has been improved and selected over generations in this species so that they detect objects through smell and help humans to locate different items, such as explosives or narcotics (Bernabeu et al., 2013). However, genetic selection for olfaction abilities did not occur in all dog breeds, as breeding for short noses in breeds like Bulldogs, Pugs or Boston terriers (between others), has had a detrimental effect on olfaction (Polgár et al., 2016).

In Spain, the National Police Unit of Canine Guides, located in Madrid, was founded in 1945, with the aim of tackling a series of complex activities by the use of the dog's sense of smell, which proved more efficient and reliable than various analytical methods. These police dogs participate on a daily basis in all the actions carried out by the different units of the National Police force.

Submitted, 03/10/2024
Accepted, 04/05/2024

According to that, they have been specially trained to maximize their search capabilities and are required to maintain levels of intense concentration during the time they spend searching for the target. Besides, they are exposed to continuous potentially stressful stimuli that could lead to behavioural and/or health problems that might shorten their lifespan.

Stress is an adaptive biological response caused when an individual perceives a threat to their homeostasis, that is, a change in their regular environment which disturbs their normal rhythm (Chrousos & Gold, 1992). In a situation where stress is present for a short period of time (acute stress), the animal acquires temporary physiological changes that helps the individual to respond and adapt to the stimulus. While, in a situation where stress occurs over a continuous period of time (chronic stress), it can lead to a wide range of pathological phenomena in the animal, such as muscular fatigue, hypertension, alteration of the immune system or infertility (Herman & Cullinan, 1997).

However, the existing range of techniques available to determine stress in animals presents a series of associated problems (Valera et al., 2012). First of all, many of these techniques involve an invasive method, since they require the animal to be restrained at the time of measurement, which can cause stress peaks at that specific moment, thus biasing measurement. Secondly, the classical methods involve obtaining parameters that are hard to analyse outside a laboratory, as specialized instruments are required.

Several studies have investigated the use of infrared thermography (IRT) as a non-invasive tool capable of detecting heat emitted from the surface of the caruncle in the eye as a sign of stress and welfare in different animal species, as cattle (Stewart et al., 2005); sport horses (Valera et al., 2012; Sánchez et al., 2016); pigs (Weschenfelder et al., 2013); fattening rabbits (Jaén-Téllez et al., 2021) and also in dogs (Redaelli et al., 2014; Travain et al., 2015; Bartolomé et al., 2021).

On the other hand, heart rate is regarded as another suitable tool to investigate the role of stress on welfare and performance (Reefmann et al., 2009; Grandi & Ishida, 2015; Zebunke et al., 2011).

The police dogs usually face a variety of cognitive challenges, both in their initial training and throughout their working lives. It is therefore possible that individual differences in dog cognition shown confronting a simulation of these challenges account for the variation in aptitude for working roles, and hence, their success at pursuing different kinds of targets (Bray et al., 2017).

The main aim of this study was to evaluate stress and behavior differences in working police dogs due to different scenarios and distractors according to type of training: detecting narcotics or explosives.

Material and Methods

All procedures used in this study complied with the ARRIVE guidelines and were carried out in accordance with the U.K. Animals (Scientific Procedures) Act, 1986 and associated guidelines, with the EU Directive 2010/63/EU for animal experiments, or the National Research Council's Guide for the Care and Use of Laboratory Animals ethical guidelines.

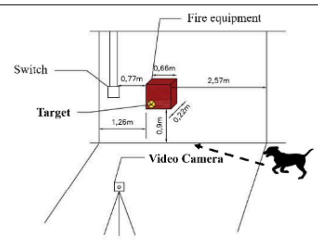
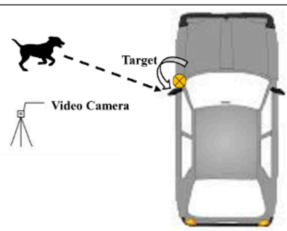
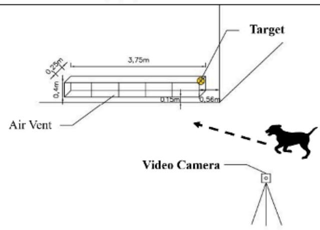
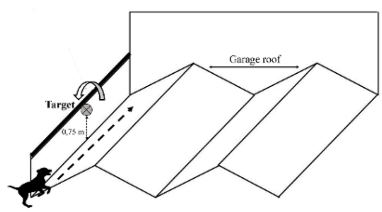
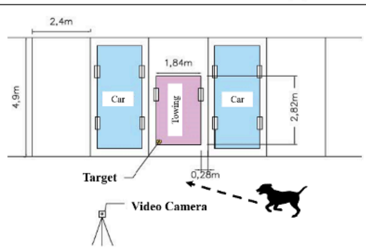
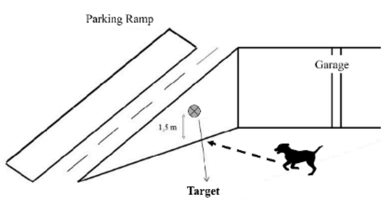
Animals

A total of 18 working dogs (14 males and 4 females) were measured. 8 of these working dogs were trained for narcotics detection (6 males and 2 females) and 10 were trained for explosives detection (8 males and 2 females). These training differences refer basically to target-signaling differences, by which narcotic-detection dogs learned to mark the target by scratching the ground and barking, whereas explosives-detection dogs learned to mark the target by sitting quietly just beside it. The dogs were trained by 9 different trainers: each trainer was responsible of 2 dogs, one explosives-detection' and one narcotics-detection' dog (except for 1 trainer that handled 2 explosives-detection' dogs). During the experiment, each dog was handled only by its trainer, in order to simulate a regular working day. The dogs belonged to 2 different breed types: Shepherd breeds (7 German Shepherd; 1 Border Collie and 4 Belgian Malinois) and Retriever breeds (2 Labrador; 2 Spanish Water Dog and 2 Bracco). The dogs ranged between 2 and 8 years old.

Experiment design

The experiment was developed at the facilities of the Spanish National Police Canine Unit, located in Seville (Spain). In order to test the stress reaction of dogs in different common environments, three scenarios were developed for each type of training (narcotics or explosives detection), being differentiated by the difficulty to get the target, with Scenario 1 (S1) being the easiest one or least challenging for the dog, Scenario 2 (S2) an intermediate-difficulty experiment and Scenario 3 (S3) being the most difficult and challenging one. Despite scenarios were different due to type of training' requirements, they were design to be comparable on difficulty. Scenarios 1 and 3 were carried out indoors, at an underground parking from the Spanish National Police facilities; whereas S2 was carried out outdoors, in the surroundings of the previous underground parking. The scenarios were developed with the help of the police dog's trainers, due to circumstances previously perceived as very common, problematic or difficult by the dogs. Then, the test developed on these scenarios were performed a second time, one week later, but including an environmental distractor. The distractor was different for each scenario, but the same between training types: a cotton with gasoline put all over the target (olfactory distractor) for S1 (S1D1), an ultrasonic whistle for hunting dogs blown with regular and intermittent sounds during the whole scenario (auditory distractor) for S2 (S2D2) and releasing an articulated snake toy with autonomous movement and bright colors around the scenario (visual distractor) for scenario 3 (S3D3) (See **Table 1** for scenarios and distractor's details).

Table 1. Differences between scenarios according to training type.

<table>
<tr><th>Scenario</th><th>Narcotics Detection</th><th>Explosives Detection</th><th>Environmental Distractor</th></tr>
<tr><td>1. Easy.
Indoor
S1</td><td>
</td><td>
</td><td>D1 - Olfactory distractor
</td></tr>
<tr><td>2. Medium.
Outdoor
S2</td><td>
</td><td>
</td><td>D2 - Auditory distractor
</td></tr>
<tr><td>3. Difficult.
Indoor
S3</td><td>
</td><td>
</td><td>D3 - Visual distractor
</td></tr>
</table>

The experiment was carried out during two weeks, with the first week measuring all 18 dogs for S1, S2 and S3 during 2 consecutive days (9 dogs per day in a 4-hour session per day), with a mean environmental temperature of 17.2ºC (range of 3.4ºC) and 68.4% mean relative humidity (range of 15%). And the second week measuring the same 18 dogs for S1D1, S2D2 and S3D3, also during 2 consecutive days, with a mean environmental temperature of 18.4ºC (range of 2.6ºC) and 66.4% mean relative humidity (range of 13%). Hence, each dog developed 6 different situations within 3 different scenarios, with a total of 108 scenarios displayed by all dogs. Thus, physiological and behavioral data from each dog was obtained from each scenario.

Physiological parameters measurements.

The animals' stress levels were measured with eye temperature (ET), assessed with infrared thermography, and heart rate mean (HR) assessed with a HR monitor attached to the animal.

Eye temperature images were taken with a portable IRT camera (FLIR E60, FLIR Systems AB, Danderyd, Sweden) by a qualified veterinarian, who was already trained in the use of the camera, being the only person in charge of this data collection. To calibrate the camera results, the environmental temperature and relative humidity were recorded with a digital thermo-hygrometer (Extech® 44550) every time an eye temperature sample was taken. An image analysis software Flir Tools+ (FLIR Systems AB, Sweden) was used to measure eye temperature, using the maximum temperature (ºC) recorded on the eye caruncle, according to Valera et al. (2012). Two images were taken per animal on each scenario, just after the objective was marked; later, the best photo for each scenario was used for the analyses.

In addition, HR were monitored with a Polar H10® chest strap synchronized with Kubios® app and quantified as heart beats per minute (bpm). The strap was placed around the thoracic cavity of the animal, adjusted to the height of the heart, over the second intercostal space and thoracic vertebrae 5 to 8 (T5 to T8), just behind the radio-humeral-ulnar joint or pectoral elbow joint of the dog, ensuring its stability and fixation. With the placement of this tape, the data of dog's cardiac activity was recorded throughout the exercise, being able to collect it on a mobile device via Bluetooth. The HR was recorded from the moment the dog begun searching the target in the scenario, until the dog marked it. For analyses purposes, the mean cardiac activity (in bpm) recorded during each scenario was computed, so that only one HR value was obtained per scenario.

In order for the dogs to get used to the operators, the HR chest stripe and the IRT camera, a short habituation period was carried out 24h-48h before the first day with all the dogs. During this habituation period, the heart rate chest strap was left on each dog during 5 minutes and they could freely sniff the infrared camera and the camera operator all the time.

Behavior measurements

Behavior was recorded for each animal on each scenario, from the moment they started searching the target in the scenario, until the animal marked it, with a total of 6 behavioral video-recordings per dog and 108 recordings from all dogs analyzed. All exercises were recorded with a GitUp Git2P Pro® 2160P video camera with a Panasonic sensor. Then, in order to assess behavior of dogs in every scenario, these recordings were analyzed with The Observer XT software (Noldus Information Technology, 2019) and coded using a non-standardized behavior ethogram, developed following Willis (1995) previous findings (**Table 2**). This list included 17 behavior parameters, 13 of them were identified in all scenarios (S1, S2, S3, S1D1, S2D2 and S3D3) and 4 parameters were identified only during scenarios with environmental distractors (S1D1, S2D2 and S3D3). There were 3 behavioral parameters recorded as "duration" (time that the behavior is being displayed during the scenario, recorded in seconds) and 14 parameters recorded as "repetitions" (number of times that this specific behavior appears during the scenario). All videos were coded by the same person, a specialist who was previously trained.

Table 2. Description and measure of coded behaviors and behavioral categories recorded during the different scenarios.

Behavior	Description and type of measurement	N / Time (sec.)	Measured
Time to mark the target (scenario duration)	The time (s) elapsed from the time the handler gives the dog the exit signal until the animal finds the object and marks it is counted.	Time	S1 S2 S3 S1D1 S2D2 S3D3
Tail position	The position of the tail is marked (1 = high; 2 = horizontal; 3 = low; 4 = between the legs) at the exact moment in which he positions it. Changing the posture class overrides the previous position.	Time	
Ear position	The position of the ears (1 = up, attentive; 2 = down, relaxed; 3 = back, fear/aggression) is recorded at the exact moment in which it is positioned. When changing posture, the previous position is canceled.	Time	
Helping signals from trainer	Number of times the trainer points directly at the target is counted.	N	
Dog looks towards trainer	Number of times the trainer helps the dog to find the target, either with auditory signals (whistles or calls) or with gestures (pointing the area where the animal should continue searching).	N	
Passes the target without marking it	Number of times the dog passes in front of the target without marking it.	N	
Goes out of sight	Number of times the dog disappears from the field of view of the camera.	N	
Sniffs the target without marking it	Number of times that the dog sniffs the area of the target without marking it	N	
Marks the wrong target	Number of times the dog marks a wrong area.	N	
Pee	Number of times the dog pees during scenario	N	
Defecate	Number of times the dog defecates during scenario	N	
Moans	Number of times the dog moans during scenario	N	
Barks	Number of times the dog barks during scenario	N	
Approaches the distractor (<1m)	Number of times the dog physically approaches the distractor element less than 1 meter.	N	S1D1 S2D2 S3D3
Smells/Touch the distractor	Number of times that the dog approaches the distractor, smells it and/or actively touches it.	N	
Looks at the distractor	Number of times that the dog looks at the distractor, without touching it.	N	
Flight/fear of the distractor	Number of times the dog reacts by fleeing from the distractor.	N	

S1 is scenario 1, S2 is scenario 2, S3 is scenario 3, S1D1 is scenario 1 with distractor 1, S2D2 is scenario 2 with distractor 2, S3D3 is scenario 3 with distractor 3, N is frequency of the behavior, Time is duration of the behavior (in seconds).

These parameters were then grouped in 3 behavior aggrupation's according to the behavioral aspect they were recording, that were counted in 4 scores each: Attention, Effectiveness and Fear, following Willis (1995) and Dyjak et al., (2021) previous behavior aggrupation's. Thus, for each session and dog recording, an Attention, an Effectiveness and a Fear score was assigned, according to the combination of the behavioral parameters recorded. Behavior parameters recorded as duration, were calculated as the percentage of the total duration of the scenario (time to mark the target) during which the animal displayed that behavior. Thus, the different behavioral aggrupation's were classified with the following criteria:

- **Attention**: Included the parameters percentage of 'time with tail up' and percentage of 'time with ears up', recorded as duration.
  - Score 1: no attentive, with 0% of time with tail up and 0% of time with ears up.
  - Score 2: 50% of time with tail up and 0% of time with ears up.
  - Score 3: 50% of time with tail up and 50% of time with ears up, or vice versa.
  - Score 4: 100% of time with tail and ears up.
- **Effectiveness**: Included the parameters 'helping signals', 'passes the target without marking it', 'going out of sight', 'sniffing the target without marking it' and 'wrong markings', recorded as repetitions.
  - Score 1: 8 or more repetitions of any behavior.
  - Score 2: 5 to 7 repetitions of any behavior.
  - Score 3: 2 to 4 repetitions of any behavior.
  - Score 4: 0 to 1 repetition of any behavior.
- **Fear**: Included the parameters 'time with ears backwards', recorded as duration; and the parameters 'moan', 'barks', 'runs away from the distractor' and 'put the tail between the legs', recorded as repetitions.
  - Score 1: 100% of time with ears backwards and 2 or more repetitions of any of the other behaviors.
  - Score 2: 50% of time with ears backwards and 0 to 1 repetitions of any of the other behaviors.
  - Score 3: 1 to 49% of time with ears backwards and 0 to 1 repetitions of any of the other behaviors.
  - Score 4: 0% of time with ears backwards and 0 repetitions of any of the other behaviors.

  The scores scale for the three behavioral aggrupation's' was set according to police guides' professional opinion about what qualities should have an adequate police-dog: with lower scores defining "worst police-dog qualities" (minimum attention, minimum effectiveness and maximum fear) and higher scores, defining the "best police-dog qualities" (maximum attention, maximum effectiveness and minimum fear).

Statistical Analyses

For the statistical analyses, eye temperature (ET) and heart rate (HR) were the physiological variables assessed for this study.

Normality of the physiological data analyzed was assessed using a Shapiro-Wilk test (results not shown), with ET and HR following a normal distribution. Therefore, parametric analyses were used in this study for all variables.

A descriptive analysis was computed for physiological variables, according to scenario and training type.

Next, to test the influence of the 6 different scenarios (S1, S2, S3, S1D1, S2D2, S3D3) and behavioral effects (attention, effectiveness and fear) on the physiological parameters assessed during different scenarios, a General Lineal Model was computed, according to training type. Then, a Least Square Means with a Tuckey post-hoc analysis was performed only for those effects that resulted statistically significant ($p<0.05$) in the previous analysis.

As regards to behavioral aggrupation's, to assess differences between dog's behaviors due to training type, a frequency test and a Mann-Whitney U test was developed for each behavior aggrupation due to the scores distribution of these variables.

Finally, to assess the relation between behavioral aggrupation's and physiological parameters, Pearson's correlations were developed, according to training type.

All analyses were computed with the 'Statistica for Windows' software v. 12. (Stat Soft. Inc. Tulsa, OK, USA).

Results

The descriptive analysis for ET and HR physiological variables (**Table 3**), showed higher ET means in dogs trained for explosives' detection for most of the scenarios, except for S3D3, where both dogs types showed the same ET value (36.6). Besides, dogs trained for explosives' detection also showed the highest maximum ET value (42.0 ºC) and coefficient of variation (5.5%) in S2 and the minimum coefficient of variation in S3 (2%), whereas, dogs trained for narcotics' detection, showed the lowest minimum ET value in S1 (32.1 ºC).

Table 3. Descriptive analysis for Eye Temperature measured in Celsius degrees (ET (ºC)) and Hear Rate measured in beats per minute (HR (bpm)) measurements due to scenario and training type.

Training Type	Scenarios	N	**ET** (ºC)				**HR** (bpm)			
			Mean(±S.E.)	Minimum	Máximum	CV(%)	Mean(±S.E.)	Minimum	Máximum	CV(%)
Narcotics	S1	8	35.9 (±0.39)	34.2	37.2	3.1	144.9 (±14.15)	70.6	179.5	27.6
	S2	8	37.5 (±0.49)	36.0	40.2	3.7	141.6 (±10.85)	74.4	173.1	21.7
	S3	8	36.5 (±0.45)	34.8	38.1	3.5	139.1 (±12.09)	75.2	173.3	18.5
	S1D1	8	35.9 (±0.53)	32.1	36.8	4.3	138.6 (±17.36)	71.0	210.9	35.4
	S2D2	8	36.9 (±0.59)	33.3	37.9	4.6	150.8 (±14.72)	97.0	209.9	27.6
	S3D3	8	36.6 (±0.36)	34.8	38.0	2.8	124.8 (±13.83)	91.5	167.6	24.8
Explosives	S1	10	36.6 (±0.33)	34.8	37.8	2.8	122.4 (±7.57)	77.5	153.6	19.6
	S2	10	38.8 (±0.68)	36.2	42.0	5.5	138.2 (±12.26)	80.8	189.4	28.0
	S3	10	36.9 (±0.24)	35.6	38.2	2.0	136.8 (±10.84)	96.0	198.4	25.1
	S1D1	10	36.1 (±0.36)	34.6	37.8	3.2	129.0 (±8.64)	74.3	160.1	21.2
	S2D2	10	37.9 (±0.51)	35.9	41.8	4.3	154.4 (±14.22)	89.6	208.4	29.1
	S3D3	10	36.6 (±0.31)	34.6	38.0	2.7	150.2 (±10.87)	97.0	185.5	22.9
All Scenarios without distractor		54	37.1 (±0.22)	34.2	42.0	4.3	136.6 (±4.50)	70.6	198.4	24.2
All Scenarios with distractor		54	36.5 (±0.20)	32.1	41.8	4.1	142.5 (±5.23)	71.0	210.9	27.0
All Scenarios		108	36.8 (±0.15)	32.1	42.0	4.3	139.5 (±3.45)	70.6	210.9	25.7

S1 is scenario 1 (easy indoor), S2 is scenario 2 (medium outdoor), S3 is scenario 3 (difficult indoor), S1D1 is scenario 1 with distractor 1 (olfactory distractor), S2D2 is scenario 2 with distractor 2 (auditory distractor), S3D3 is scenario 3 with distractor 3 (visual distractor), CV (%) is coefficient of variance calculated in percentage, S.E. is standard error.

As regards to HR, the highest mean was shown by dogs trained for explosives' detection in S3D3 (154.4 bpm), showing also the lowest HR mean in S1 (122.4 bpm). Dogs trained for narcotics' detection showed the highest maximum values in S1D1 (210.9 bpm) and the lowest minimum values in S1 (70.6 bpm).

Table 4. General Linear Model analysis (GLM) and Least Square Means and Tuckey post-hoc analysis (LSM) for the variables eye temperature (ET) and heart rate (HR), according to environmental and behavioral effects. Results were divided for Narcotics and Explosives training types.

	Effect	Analysis	Narcotics		Explosives	
			ET	HR	ET	HR
Environmental Effects	Scenario (S1, S2, S3, S1D1, S2D2, S3D3)	GLM	*	n.s.	***	n.s.
		LSM	S1^{b}; S2^{a}; S3^{ab}; S1D1^{c}; S2D2^{bc}; S3D3^{ab}		S1^{c}; S2^{a}; S3^{c}; S1D1^{c}; S2D2^{b}; S3D3^{c}	
Behavioural Effects	Attention (sc1, sc2, sc3, sc4)	GLM	*	n.s.	n.s.	n.s.
		LSM	sc2^{b}; sc3^{b}; sc4^{a}			
	Effectiveness (sc1, sc2, sc3, sc4)	GLM	n.s.	n.s.	*	n.s.
		LSM			sc1^{b}; sc2^{b}; sc3^{b}; sc4^{a}	
	Fear (sc2, sc3, sc4)	GLM	n.s.	n.s.	n.s.	n.s.
		LSM				

n.s. is not statistically significant, *p<0.05, **p<0.01, ***p<0.001, sc1=score 1, sc2=score 2, sc3=score 3, sc4=score 4; S1 is scenario 1, S2 is scenario 2, S3 is scenario 3, S1D1 is scenario 1 with distractor 1, S2D2 is scenario 2 with distractor 2, S3D3 is scenario 3 with distractor 3, In Tuckey post-hoc analysis, different letters indicated statistically significant differences (p<0.05) between means, with letters in descending order.

Differences in the physiological variables evaluated, according to different environmental and behavioral effects was computed in **Table 4**. As regards to environmental effects, ET variable showed statistically significant differences for scenario in both narcotics' (p<0.05) and explosives' (p<0.001) trained dogs, with S2 showing the highest ET values and S1D1 the lowest. According to behavioral effects, statistically significant differences (p<0.05) were found for attention in narcotics' trained dogs and for effectiveness in explosives' trained dogs, with score 4 showing the highest ET means for both behavioral aggrupation's. On the other hand, HR variable showed no statistically significant differences (p>0.05) for any environmental or behavioral effects.

In order to ascertain differences in behavioral aggrupation's due to training type, frequency of animals over a 0-100% scale and Mann-Whitney U Test between means, was shown in **Figure 1**. Statistically significant differences (p<0.05) were observed between narcotics and explosives' trained dogs for Attention and Effectiveness behavioral aggrupation's. So that, explosives' trained dogs showed higher Attention scores but lower Effectiveness scores than Narcotics' trained dogs, with both type of dogs showing similar Fear scores.

Finally, the relation between behavioral aggrupation's and the physiological parameters evaluated was assessed in **Table 5**. ET showed medium and positive statistically significant (p<0.05) correlations with Attention in narcotics' trained dogs (0.34) and with Fear in explosives' trained dogs (0.26), so that, the higher the ET value, the higher the Attention and the Fear scores, respectively.

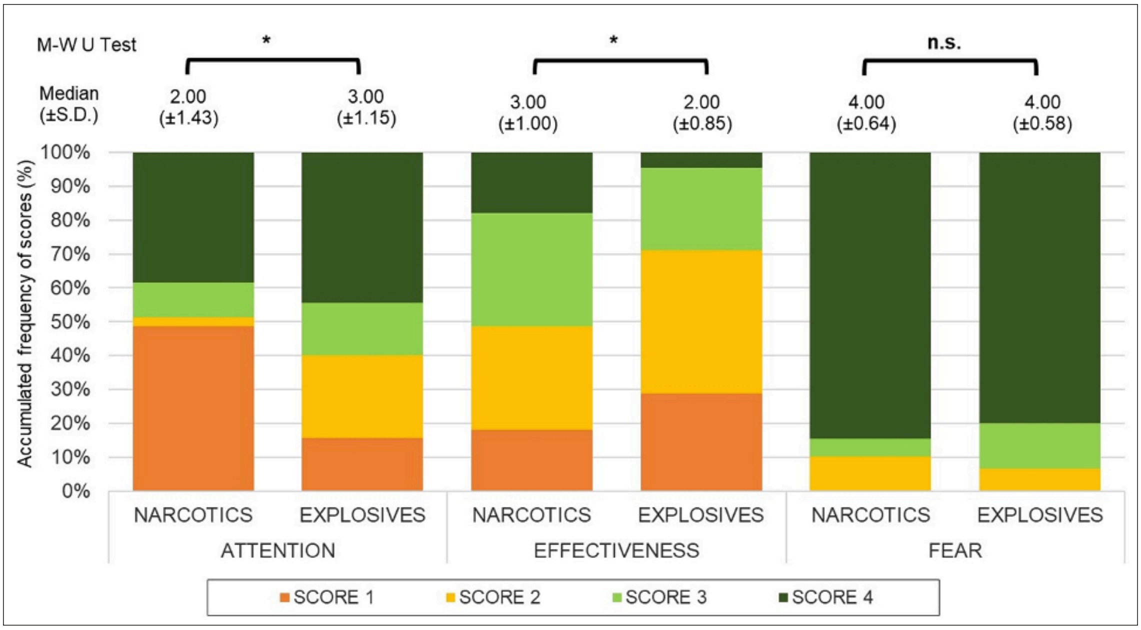


Figure 1. Accumulated frequency of scores (in percentage), median and standard deviation (S.D.) and Mann-Whiney U test between medians of recorded police dogs for attention, effectiveness and fear behavioral aggrupations, according to training type.

Where Scores goes from 1 (lowest attention and effectiveness signs and highest fear signs) to 4 (highest attention and effectiveness signs and lowest fear signs). * $p<0.05$ and n.s. is not statistically significant.

HR parameter showed a medium and negative statistically significant ($p<0.05$) correlation with Attention in narcotics' trained dogs (-0.31), so that, the higher the attention, the lower the HR in these dogs. When all animals were considered, only statistically significant ($p<0.05$) correlations were found with Attention, being medium and positive (0.26) with ET and medium and negative (-0.23) with HR. These results highlighted an opposite relation of Attention behavioral parameter with ET and HR physiological measurements, that gets stronger in narcotic's trained dogs. So that, the higher the attention of the dog, the higher the ET level and the lower the HR.

Table 5. Spearman Rank correlations between behavioral aggrupation's and physiological parameters assessed in dogs, according to training type.

	NARCOTICS		EXPLOSIVES		ALL DOGS	
	ET	HR	ET	HR	ET	HR
Attention	**0.34***	**-0.31***	0.22	-0.20	**0.26****	**-0.23***
Effectiveness	-0.10	-0.03	0.14	-0.03	-0.04	0.01
Fear	0.11	-0.11	**0.26***	-0.07	0.15	-0.08

Where ET is eye temperature; HR is heart rate; n.s. is not statistically significant, *$p<0.05$, **$p<0.01$, ***$p<0.001$.

Discussion

With this study, we evaluated stress and behavior differences in narcotics and explosives' trained police dogs, confronted to different scenarios and environmental distractors, in order to get valuable information for these dog's selection and daily training.

In our study, police dogs trained for explosives' detection showed, in general, the highest mean, maximum and coefficient of variation ET and HR values, indicating higher stress and excitability levels associated with this type of training. Furthermore, these stress levels were also associated to the S2 and the S3D3 scenarios (respectively), probably due to the first one was developed outdoors, increasing the environmental influence on dog's stress; whereas the second one showed the highest difficulty and a visual distractor, that could have considerably increased the excitability levels in these dogs. Previous authors have reported infrared thermography and heart rate as an adequate tool to assess stress in working animals (Redaelli et al., 2014; Tiira et al., 2020; Bartolomé et al., 2021; Dyjak et al., 2021), reporting also similar differences in ET and HR values due to explosives' detection trained dogs. This could be due to this training type demands more concentration from dogs due to the delicate nature of the target (Alexander et al., 2011).

According to the variance' and least square means analyses, statistically significant differences ($p<0.05$) were found in the physiological variables analyzed in this study due to different environmental and behavioral effects.

As regards to scenarios, findings in both narcotics and explosives' trained dogs comprised a general perception of S2 scenario as more stressful, probably due to it was developed outside, with more environmental interactions and weather influence. Findings in S2 indicate that police dogs' tendency to perceive their environment with more stress, produces a physiological activation that may increase their concentration and thus help to find the target more quickly and efficiently (Riva et al., 2012; Beerda et al., 2000).

The behavioral aggrupation's evaluated indicated that narcotics' trained animals with higher attention levels showed also higher ET. These results indicated higher efforts in these dog's training technics to obtain adequate obedience and control over the animal (Rocznik et al., 2015; Tiira et al., 2020). Vas et al. (2007) also found that more experienced dogs use to show less inattention behaviors. On the other hand, our results also showed that explosives' trained animals with higher effectiveness levels showed also higher ET. It corroborates previous results, associating this physiological increases with better concentration to find the target, leading to more effective results. Previous behavioral studies in police dogs have found similar behavioral characteristics considered important for dog handlers (Wilsson and Sundgren, 1997; Rocznik et al., 2015; Sherman et al., 2015). Furthermore, comparisons of these behavior parameters with physiological signs in police dogs have also been developed previously (Riva et al., 2012; Beerda et al., 2000), despite no infrared thermography analyses were made. As regards to Fear, no differences were found in ET or HR parameters. These results were in line with Adamkieweicz et al. (2013), that reported no differences in fear reactions between both training types police dogs, when evaluating them by their handlers and trainers. This could be probably due to the physiological response triggered was so light that did not make any difference on their outside behavior, despite showing differences in stress levels.

However, our results from the accumulated frequencies in behavioral scores, also showed that explosives' trained dogs had lower effectiveness scores than narcotics' trained dogs. This implied a higher frequency of marking the wrong target, passing the target without marking and/or searching very far from the target location. Previous studies have reported different factors, beyond physiology, determining the effectiveness of detection dogs, such as the handler-dog dyad (Lefebvre et al., 2007; Lit et al., 2011), dog maturation, trainer experience, and amount of training provided (Jezierski et al., 2014; Hayes et al., 2018), that could be biasing results for these animals.

On the other hand, results found for fear score corroborated previous studies indicating low fear scores and high emotional resilience for fearful stimuli in police dogs, regardless the training type (Blackwell et al., 2013; Sherman et al., 2015).

Finally, the correlation analysis corroborates previous findings in this study, with Attention being the behavioral aggrupation that is more related to physiological changes, so that, the higher the attention, the lower the excitability (HR) and the higher the stress (ET) in narcotics' trained dogs and in all dogs. Sacharczuk et al. (2019) found genotype differences associated with olfactory and neurotransmitters receptors, in narcotics and explosives detection dogs that could lead into different physiological ways on perceiving different targets and could thus, define their physiological response. Previous studies reported differences in ET and HR physiological basis, with ET being controlled by parasympathetic part of the autonomous nervous system (Bartolomé et al., 2013), and HR being controlled by the sympathetic part of it. Kuwahara et al. (1996) also found that the parasympathetic part of the autonomic nervous system had primary regulatory function in the response to low-intensity exercise, whereas the sympathetic activity increased only when the behavioral stress response was expressed with substantial flight or fight reactions. Thus, when the dog is showing the highest levels of attention, remains calm and focused on the target, thus increasing the parameters controlled by the parasympathetic via (ET) and decreasing the parameter controlled by the sympathetic via (HR).

Conclusions

Differences in behavioral and physiological parameters were found in police dogs due to their training for either narcotics or explosives' detection. Our results indicated that environmental distractors included did not alter much their physiology. Furthermore, explosives' detection dogs showed more excitability, and less effectiveness behavioral signs than narcotics' detection dogs, with no differences found related to fear signs. An opposite relation was found of Attention with HR and ET parameters, so that, the higher de attention, the higher the ET and the lower the HR, this could be due to a parasympathetic basis of the ET physiology against a sympathetic control of the HR, that appeared when the dog is showing the highest levels of attention. Eye temperature assessed with infrared thermography, appeared as an effective, non-invasive tool to assess stress in police dogs during target-detection trainings. However, further studies should be made to corroborate the results found.

Authorship Statement

The idea for the paper was conceived by MV. The experiments were designed by MV and EB. The experiments were performed by EB, DIP-G. The data were analyzed by EB, MJS-G. The paper was written by EB, MV, MJS-G, DIP-G.

Acknowledgements

The authors would like to thank the Canine Unit of the Spanish National Police institution, located in Seville (Spain), for the kind collaboration of their staff and animals in the study. This research has been partially financed by the VI PPIT-US.

Conflict of Interest Statement

The authors declare no conflict of interest.

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Valutazione dello stress e del comportamento nei cani poliziotto a causa di situazioni difficili: differenze dovute agli obiettivi formativi

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Sintesi

I cani poliziotto sono stati addestrati per massimizzare le loro capacità di ricerca e sono tenuti a mantenere livelli di intensa concentrazione durante il loro orario di lavoro. Lo scopo principale di questo studio era di valutare le differenze di stress e comportamento nei cani poliziotto dovute a diversi scenari e distrattori a seconda del tipo di addestramento: rilevamento di narcotici o esplosivi. Sono stati misurati un totale di 18 cani (14 maschi e 4 femmine). 8 sono stati addestrati per il rilevamento di narcotici e 10 per il rilevamento di esplosivi. Per testare la reazione allo stress dei cani, sono stati sviluppati 3 scenari per ciascun tipo di addestramento, differenziati in base alla difficoltà, Scenario 1 quello più semplice, Scenario 2 un test di difficoltà intermedia e Scenario 3 quello più impegnativo. Quindi, questi scenari sono stati eseguiti una seconda volta, includendo un distrattore ambientale: un distrattore olfattivo per S1 (S1D1), un distrattore uditivo per S2 e un distrattore visivo per lo scenario 3. I livelli di stress degli animali sono stati misurati con la temperatura oculare (ET), valutato con termografia a infrarossi e frequenza cardiaca (HR). Il comportamento è stato registrato per ciascun animale in ciascuno scenario. Questi parametri sono stati poi raggruppati in 3 aggregazioni comportamentali conteggiate in 4 punteggi ciascuna: Attenzione, Efficacia e Paura. Un'analisi descrittiva ha mostrato medie ET più elevate nei cani addestrati per il rilevamento di esplosivi per la maggior parte degli scenari. Un modello lineare generale e un'analisi post-hoc di Tuckey per diversi effetti ambientali e comportamentali, hanno rilevato che l'ET ha mostrato differenze statisticamente significative per l'effetto dello scenario con cani addestrati sia per narcotici che per esplosivi, con S2 che mostra i valori ET più alti e S1D1 il più basso, mentre , in base agli effetti comportamentali, sono state riscontrate differenze statisticamente significative per l'attenzione nei cani addestrati agli narcotici e per l'efficacia nei cani addestrati agli esplosivi, con il punteggio 4 che mostra le medie ET più alte per entrambi gli aggruppamenti comportamentali. D'altra parte, il test U di Mann-Whitney tra le medie dei comportamenti, ha dimostrato che i cani addestrati agli esplosivi hanno mostrato punteggi di attenzione più alti ma punteggi di efficacia inferiori rispetto ai cani addestrati agli narcotici. Infine, l'ET ha mostrato correlazioni medie e positive statisticamente significative con l'Attenzione nei cani addestrati agli narcotici (0,34) e con la Paura nei cani addestrati agli esplosivi (0,26), il parametro HR ha mostrato una correlazione media e negativa statisticamente significativa con l'Attenzione nei cani addestrati agli narcotici (-0,31). I nostri risultati hanno indicato che i cani per il rilevamento di esplosivi hanno mostrato maggiore eccitabilità e segni comportamentali meno efficaci rispetto ai cani per il rilevamento di narcotici, senza differenze riscontrate relative ai segni di paura.