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Creation of training aids for human remains detection canines utilizing a non-contact, dynamic airflow volatile concentration technique

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ABSTRACT

Human remains detection (HRD) canines are trained to locate human remains in a variety of locations and situations which include minimal quantities of remains that may be buried, submerged or extremely old. The aptitude of HRD canines is affected by factors such as training, familiarity with the scent source and environmental conditions. Access to appropriate training aids is a common issue among HRD canine handlers due to overly legal restrictions, difficulty in access and storage, and the potential biological hazards stemming from the use of actual human remains as training aids. For this reason, we propose a unique approach of training aid creation, utilizing non-contact, dynamic air-flow odor concentration onto sorbent materials. Following concentration, the sorbent material retains the odor from the scent source composed of volatile organic compounds. The sorbent material containing the odor can then be utilized as a canine training aid. Training materials prepared in this manner were tested under a variety of conditions with many HRD canines to demonstrate the efficacy of the new training aids. A high level of correct canine responses to the new training aids was achieved, approaching 90%, with minimal false positives.

1. Introduction

Canines have been used as scent detectors for thousands of years [1]. The earliest detector canines were used to locate prey when hunting with their masters. Their ability to hunt and locate prey comes naturally, as all canines, domesticated and wild, have a natural drive to hunt and a keen ability to detect the particular scent given off by the prey object [2]. The use of scent canines has evolved from merely a hunting tool to a detection device used by many government and law enforcement agencies, as well as private entities. Current uses of scent canines include, but are not limited to, the detection of drugs, explosives, accelerants, humans (living and deceased), agricultural products, currency, melanoma and pests [3].

The specialty of human remains detector (HRD) canines, also known as cadaver dogs or victim recovery dogs, evolved from the search and recovery discipline. Search and rescue canines are trained to locate living humans, often in wilderness or disaster settings. While working with their search and rescue canines, handlers noticed that the canines would lose the scent path if the living person had expired, as the change from living human odor to deceased human odor was unfamiliar to these canines [4]. Based on these observations, a new class of detector dogs, HRD canines, was initiated.

Human remains detector canines are trained to locate human remains, including whole bodies, body parts, tissue, blood, bone and decomposition fluids. Several published studies focused on the capability of human remains detection canines, including the use of canines to locate extremely small or aged scent sources, such as human teeth, scattered remains, old graves, and materials that had indirect contact with remains materials. These studies show that HRD canines are adept at locating minimal quantities of odor, including buried and aged remains. However, the canines' performances can be affected by training, familiarity with the scent source, and environmental conditions [4–7].

In real life scenarios, the canine may be asked to search for a range of odors, from fresh bodies, putrefied bodies in the height of odor production, to ancient skeletal remains. The odor source may be a whole body, body parts, tissue or blood. For canines to locate all types and ages of human remains, it is imperative that handlers use an assortment of training aids when possible. Training aids commonly include human bone, gauze that has been soaked in decomposition fluid, blood, adipocere, grave dirt, and articles or clothing previously in contact with remains [6,8,9]. These training aids are difficult to obtain due to limited access imposed by legal restrictions and are potential biohazards [7].

Human tissue is considered to be a reliable scent source and can be decomposed to different levels; however, it is particularly

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difficult to obtain and has the greatest number of legal restrictions [8]. As an alternative to actual human remains, chemical pseudo scents have been used as training aids. Putrescine and cadaverine are particularly odorous compounds formed during the decomposition process and are commonly found in pseudo scent mixtures. While these compounds may be easier to obtain legally, their hazardous nature requires extra precaution during handling. Additionally, cadaverine and putrescine are not human specific as they are known to be found in all decaying organic matter [7] and have also been detected in human saliva [10]. Another drawback of pseudo scent mixtures is that there is a high likelihood that they do not represent the entire odor picture of human remains, as there have been few scientific studies showing that these particular compounds or combinations thereof are the specific odorants required by HRD canines.

A majority of HRD canine handlers in the United States and some in Europe are civilians and not directly associated with any law enforcement or government agency. Even with the many groups associated with canine human remains detection, there are no universally accepted methods for training, and there is currently no centralized organization that has established training and certification guidelines. The Scientific Working Group for Dog and Orthogonal Detector Guidelines (SWGDOG) consists of experts from local, state, federal and international agencies acting to establish best practice guidelines for detector canines, including human remains detection canines, in an attempt to improve their performance and reliability. They emphasize the need for further research in the area of human remains detection because while some research has been published on the topic, it remains minimal and inadequate. The SWGDOG subcommittee on Research and Technology has created a list of research needs for the detection canine community. In their document, SWGDOG considers the need for the development of reliable training aids to be critical, particularly for HRD canines. Improved training aids include those that are easily and legally obtainable, non-hazardous, easy to use, reusable, and representative of the whole odor picture for the canines [11].

The Scent Transfer Unit (STU-100) is a field-portable, dynamic-airflow collection device developed for the concentration of living human scent volatiles from scent samples onto a sorbent material. It consists of a small vacuum pump attached to a Teflon-coated hood designed to hold a piece of collection material. When the STU-100 is swept over the subject or object of interest, air is drawn toward the device, concentrating any volatile organic compounds (VOCs) present onto the sorbent material at the face. Following collection, the gauze pad is removed and may be presented to the canine in order to initiate a search. It is currently employed by many law enforcement and federal agencies in the United States as a method of scent collection for use with human scent canines.

Harvey and Harvey [12] demonstrated the ability of human scent detection canines to accurately trail individual humans through different environments based on the scent that was collected onto a gauze pad using the STU-100. Eight bloodhounds were run on five different trails, all between 0.5 and 1.5 miles with a "Y" shaped pattern, requiring the canine to make a decision between turning left or right. The trails were aged for 24 h prior to introduction to the canines. The trailing environments included a local park, a college campus and a downtown, urban area, all with a high amount of foot traffic making trail contamination probable. The study showed that 77.5% of all canines successfully completed the trials, demonstrating the ability of trained canines to discriminate and follow individual people based on scent collected by the STU-100.

It was further demonstrated by researchers and dog handlers at the Federal Bureau of Investigation (FBI) and the Southern California Bloodhound Coalition that the STU-100 was capable of collecting human scent from post-blast debris: A bomb was detonated and scent pads were collected from the post-blast debris using the STU-100. The scent pads were presented to twelve canine teams, which were asked to trail to the person who had handled the bomb before detonation. Of the twelve canines, 78.3% trailed to the correct person with no false positives [13].

Curran et al. [14] conducted a similar study using the STU-100 to collect human scent from post-blast debris of a roadside bomb consisting of 60 mm mortars boosted with C-4 and a peroxide bomb composed with liquid peroxide and liquid nitromethane, separately detonated. The explosive devices were handled by a human subject, detonated, and the debris was recovered. The scent evidence was collected from the debris with the STU-100, and the gauze pads were presented to canine teams. Overall, an average success from site response of 82.2% and a combined overall average success of 73.5% was reported. These studies demonstrated that trained canines can accurately trail and identify the correct subject from evidence collected with the STU-100, even under unusual or extreme situations.

As the HRD canines utilize VOCs emanating from the source of interest in the detection process, the approach employed here was to create canine training aids by the pre-concentration of VOCs emanating from human remains on a suitable sorbent. The objective of the current study is to explore the effectiveness of a non-contact, dynamic airflow sampling device that can efficiently pre-concentrate human remains VOCs onto a sorbent material from the sample matrix. To the best of our knowledge, this article represents the first research study to apply scent collection by the Scent Transfer Unit (STU-100) to the creation of canine training aids. These new generation training aids are non-hazardous, easy to obtain, and represents a comprehensive odor picture for a variety of human remains odors. Such training materials were tested with HRD canines to demonstrate the efficacy of the new training aids.

2. Materials and methods

2.1. Creation of training aids

Canine training aids were made by collecting target odors with the STU-100 onto Dukal cotton gauze (DUKAL Corporation, Syosset, NY). For VOC collection from scent sources, the STU-100 was run for 1 min, one to four inches above the sample, on the lowest flow rate setting, as had previously been determined to be the optimal setting for odor concentration prior to sampling, the sorbent material was analytically cleaned using a previously developed cleaning protocol [15]. Scent sources included freshly deceased human remains, fresh canine and chicken remains, cremated human remains (cremains) and gauze material containing decomposition fluid, adipocere, or blood. The remains of the human, canines and chicken were sampled directly. The decomposition fluid, adipocere, and blood samples were in the form of gauze pads soaked in the above mediums and placed into glass jars. The odor remaining in the jars was collected with the STU-100 by placing it directly over the opening of the jars. The jars were stored below freezing temperature when not in use. An STU blank was created by collecting air from inside a clean jar onto a clean gauze pad.

For the initial canine trials, the collection material was removed from the STU-100 and sealed into low density, 1.5-mL, polyethylene, permeable bags (Veripak, Atlanta, GA), which were then sealed into aluminized, moisture barrier bags (3 M, St. Paul, MN). For supplementary canine trials, the odor samples were either sealed directly into the aluminized bags or placed into glass jars with plastic, perforated lids (Bed, Bath and Beyond, Inc.).

2.2. Canine trials

2.2.1. General set-up

In each canine trial, a row (or rows) of ten cement blocks were placed outdoors on a paved surface approximately five feet apart. The training aids were placed inside each block and left uncovered. Each block contained a training aid, a STU blank or an untreated piece of gauze. For the training aids contained in the aluminized bags, the gauze pads were removed from the bag and placed directly into the cement block. For the training aids contained in the glass jars, the outer lid was removed, exposing a plastic, perforated lid. The canines were able to sniff the odor inside of the jar, but were not able to make direct contact with the gauze pad itself even in the case that the cement block was moved.

Table 1
Training aid set up for Trial 1, Day 1.

	Set 1	Set 2	Set 3	Set 4
Block 1	–	–	–	–
Block 2	–	–	–	–
Block 3	Fresh remains 1	–	–	–
Block 4	–	Canine remains	–	–
Block 5	–	–	Positive control	–
Block 6	–	Blank gauze	–	–
Block 7	–	Positive control	–	Positive control
Block 8	–	–	–	–
Block 9	Fresh remains 2	–	–	–
Block 10	–	–	–	Cremains

For each trial, a positive control was run to ensure that the canines were responding correctly to human remains. Any canine that did not alert to the positive control was eliminated from the trial.

2.2.2. Individual trial set ups

2.2.2.1. Trial 1: preliminary trials. Four sets of ten cement blocks were placed out, each containing a piece of gauze, according to Table 1. Training aid odor sources included fresh human remains from two bodies (Fresh remains 1 and 2), cremains, as well as a STU blank. All other blocks contained untreated gauze pads.

Day 1: All training aids were sealed into permeable bags and subsequently sealed into aluminized bags. The training aids were made one day prior to the trials and were stored indoors at room temperature. Four canines were run on Day 1; canines 1 and 4 were considered novices, while canines 2 and 3 were considered experts. The experience level of the canine (i.e., expert, intermediate or novice) was dictated by the handler before the trial.

Day 2, Part 1: New training aids were made from the same scent sources as Day 1; however, this time the permeable bags were not used, as to increase the quantity of scent available to the canines. The training aids were set up according to Table 2. Canines 2, 3 and 4 were used again along with four additional canines (Canines 5–8). Canines 5, 7 and 8 were novices, and canine 6 was considered an expert.

Day 2, Part 2: In order to further increase the available odor, multiple gauze pads containing the same odor were placed in a single block. A single set of ten blocks were run. Block 1 contained four scent pads from Fresh remains 1 and one pad from Fresh remains 2; a total of five scent pads. All other blocks contained multiple gauze pads with no odor. Only the canines that previously responded correctly to the positive control were used.

2.2.2.2. Trial 2: collection method. Six training aids were prepared by collecting odor with the STU-100 and placing the collection material into separate glass jars. The jars were placed in a single line-up of ten cement blocks. The scent source that was sampled using the STU-100 was created from a piece of gauze soaked in decomposition fluids. The number of pads per training aid and the length of collection time with the STU-100 were varied (Table 3) as a method of varying the scent quantity on each gauze pad. The STU-100 blank was prepared by sampling over an empty jar of the same type. The remaining blocks contained untreated gauze pads. Six canines were used, two experts and four novices.

2.2.2.3. Trial 3: life time of scent in open jars. In order to determine how long a detectable quantity of scent would remain on a training aid exposed to the environment, a series of trials were conducted over a 24 h period. Two sets of scent samples were created from decomposition fluid on gauze pads, as well as a STU-100 blank, sampling with a single gauze pad for 3 min for each. The remaining blocks contained untreated gauze pads. A set of ten blocks was set up according to Table 4. The first trial was run immediately after opening the jars. Additional trials were run two, twelve, and 24 h after the initial opening. For the first trial (0 h), five canines, two expert and three novices, were used. For the additional trials (2 h, 12 h, and 24 h), three of the five canines were used, including two experts and one novice canine.

Table 3
Training aids created for Trial 2.

Sample	Number of gauze pads	Length of collection (min)
1	1	1
2	3	1
3	6	1
4	1	5
5	1	10
Blank	3	1

Table 4
Training aid set up for Trial 3.

Block #	Contents
Block 1	–
Block 2	Decomp 1
Block 3	–
Block 4	STU Blank 1
Block 5	–
Block 6	STU Blank 2
Block 7	–
Block 8	–
Block 9	Decomp 2
Block 10	–

2.2.2.4. Trial 4: assortment of scent sources. Five training aids and one blank were prepared using the STU-100. For each training aid, scent was collected onto a single gauze pad over a period of 3 min. The scent sources consisted of gauze material that had been soaked in decomposition fluid, soaked in blood, wiped over a freshly deceased body, or wiped over adipocere. All the scent sources were stored in separate glass jars below freezing temperatures.

Ten cement blocks were set up according to Table 5. Eight canines were used, three novices, two intermediates and three experts.

2.2.2.5. Trial 5: population study. A population study was conducted to evaluate the response of trained HRD canines to the previously developed training aids. The study was carried out utilizing 26 canines, from novice to expert, trained by different handlers or trainers and maintained under different agencies. The participating canine / handler teams included in the study are listed in Table 6 along with the estimated level of expertise, the type of positive control used during evaluation, age, and years of experience of each canine.

Each group was provided two identical sets of training aids. One set packaged in aluminized bags and the other set in glass jars. The training aids were prepared using the STU-100 on the lowest flow rate for 3 min. A single gauze pad was used for each aid. The odor sources included a STU blank, two distracters, and two human remains sources. The human remains scent sources were decomposition fluid on a gauze pad and a freshly deceased body. The distracter scent sources included the remains of a whole chicken and live human. The blank was prepared by sampling an empty glass jar. The training aids were labeled A–E, and the label for each training aid was determined by a random number generator for each training aid set. Immediately after the preparation of the training aids, the kits were mailed to each participating group with instructions to keep the kit in a freezer until use. Each group of canines involved in the trial was given specific instructions regarding trial

Table 2
Training aid set up for Trial 1, Day 2, Part 1.

Block #	Set 1	Set 2	Set 3	Set 4
Block 1	–	–	–	–
Block 2	–	Fresh remains 1	–	–
Block 3	Positive control	–	–	–
Block 4	–	–	–	–
Block 5	–	–	–	–
Block 6	–	–	–	Cremains
Block 7	–	Canine remains	–	–
Block 8	–	Blank	Fresh remains 1	–
Block 9	–	–	–	–
Block 10	–	–	–	–

Table 5
Training aid set up for Trial 4.

Block #	Contents
Block 1	–
Block 2	Blood
Block 3	Fresh remains
Block 4	Decomp fluid
Block 5	Adipocere
Block 6	STU Blank
Block 7	–
Block 8	–
Block 9	–
Block 10	–

Table 6
Canine/handler teams, experience level of such teams, and type of positive controls used in population study.

Handler/Trainer	Canine	Experience	+ Control	Age	Years of experience	Breed
Handler A	A1	Expert	Gauze with decomp fluid	8	6.5	German Shepherd
	A2	Novice	Gauze with decomp fluid	9	0.25	German Shepherd
	A3	Intermediate	Gauze with decomp fluid	5	2	Jack Russel
	A4	Intermediate	Gauze with decomp fluid	5	2	Golden Retriever
	A5	Expert	Gauze with decomp fluid	5	1.5	German Shepherd
Handler B	B1	Expert	Decomposed arm (bone and tissue)	3		Doberman
	B2	Expert	Decomposed arm (bone and tissue)	3		Labrador
Handler C	C1	Expert	Blood and grave dirt	4	1	Belgian Malinois
	C2	Intermediate	Blood and grave dirt	3.5	2	Lab/Rott mix
	C3	Expert	Blood and grave dirt	8	6	Australian Shepherd
	C4	Expert	Blood and grave dirt	8.5	6	German Pointer
Handler D	D1	Intermediate	Dried blood	3	1	German Shepherd
	D2	Expert	Dried blood	4	1.75	Golden Retriever
	D3	Expert	Dried blood	9	5	German Shorthair
	D4	Novice	Dried blood	3	0.75	Mixed
	D5	Expert	Dried blood	7	3	Belgian Malinois
	D6	Novice	Dried blood	7	0.5	Golden Retriever
	D7	Intermediate	Dried blood	3	1	Beagle Mix
Handler E	E1	Expert	Liquefied flesh	13	8	Labrador
	E2	Expert	Liquefied flesh	9	7.5	Golden Retriever
	E3	Intermediate	Liquefied flesh	3	2	German Shepherd
	E4	Novice	Liquefied flesh	3	2	Golden Retriever
	E5	Expert	Liquefied flesh	11	6	Border Collie
	E6	Novice	Liquefied flesh	5	2	Labrador
	E7	Novice	Liquefied flesh	3	1	German Shepherd
	E8	Expert	Liquefied flesh	14	8	Labrador

set up. These instructions followed the same methodology as the previous canine trials.

2.2.3. Statistical analysis

For the analysis of the results of the final canine trial, positive predictive value (PPV) and negative predictive value (NPV) were calculated. The PPV gives the probability that a positive answer is the correct answer. In other terms, it is the probability that when a canine makes an alert, the alert is correct. This is calculated by the number of true positives divided by the summation of true positives and false positives, i.e.

$$\mathrm{PPV} = \frac{\text{True Pos.}}{\text{True Pos.} + \text{False Pos.}} \quad (1)$$

Conversely, the NPV gives the likelyhood that a negative response is correct, or that when a canine is non-responsive to an aid, the non-response is correct and the aid does not contain an odor of interest. This is calculated by the number of true negatives divided by the summation of true negatives and false positives, i.e.

$$\mathrm{NPV} = \frac{\text{True Neg.}}{\text{True Neg.} + \text{False Neg.}} \quad (2)$$

3. Results

3.1. Canine training aids/canine trials

3.1.1.1. Trial 1: preliminary trials

Day 1: The training aids included odors that were collected with the STU-100 and were from two different fresh human remains, canine remains, and cremated human remains. Three positive controls and a STU blank were also placed in the blocks. The canines' responses to each block are given in Table 7.

The total number of false positives were determined by the total possible number of alerts (total number of alerts = total number of blocks × number of canines) subtracted from the number of possible correct alerts (number of possible correct alerts = number of blocks containing aids × number of canines).

All canines except for one alerted on the three positive controls; the other canine alerted on two of the three. Correctly alerting to the positive controls indicates that the canines were trained properly and ready to work. Three of the four canines alerted on the blank prepared from an untreated gauze pad, suggesting possible cross-contamination. Two of four canines alerted or showed interest to the fresh remains samples in both instances. This substantiates the use of the STU-based training aids. Only thirteen false positives were made by the canines out of a possible 132.

Day 2, Part1: For the next set of canine trials the same scent sources were used. Extra precautions were taken to prevent any cross-contamination of the blank, thus in this trial no canines alerted to the blanks. The results of this trial demonstrate interest by the canines for the STU-based training aids, but showed no improvement over Day 1 (Table 8). Canines 6 and 7 did not alert to the positive control, and thus were not included in the results. The two canines that alerted to the cremation remains (K9 5 and K9 8)

Table 7
Canine responses to training aids in Trial 1, Day 1 (A = Alert, I = Interest, 0 = No Response).

Block # (Set.Block)	Contents	K9 1 (novice)	K9 2 (advanced)	K9 3 (advanced)	K9 4 (novice)	Total
1.3	Fresh remains 1	0	A	A	0	2/4
1.9	Fresh remains 2	0	0	A	I	1(2)/4
2.4	Canine remains	I	0	0	A	1(2)/4
2.6	STU blank	0	A	A	A	3/4
2.7	Positive control	A	A	A	A	4/4
3.5	Positive control	0	A	A	A	3/4
4.7	Positive control	A	A	A	A	4/4
4.10	Cremains	0	0	0	0	0/4
–	Gauze blank	3	3	2	2	10/128
False positives		3	4	3	3	13/132

Table 8
Canine responses to training aids in Trial 1, Day 2, Part 1 (A = Alert, I = Interest, 0 = No Response).

Block # (Set.Block)	Contents	K9 2 (adv)	K9 3 (adv)	K9 4 (nov)	K9 5 (nov)	K9 6 (adv)	K9 7 (nov)	K9 8(nov)	Total
1.3	Positive control	A	A	A	A	0	0	A	5/5
2.2	Fresh remains 1	A	0	0	0	X	X	0	1/5
2.7	Canine remains	0	0	A	0	X	X	0	1/5
2.8	STU blank	0	0	0	0	X	X	0	0/5
3.8	Fresh remains 2	0	A	0	0	X	X	0	1/5
4.6	Cremains	0	0	0	A	X	X	A	2/5
–	Gauze blank	0	0	0	0	X	X	2	2/170
False positives		0	0	0	0	X	X	2	2/175

were the only two canines of the group that had previously been trained on cremains.

Day 2, Part 2: Of the five canines, all alerted to the block containing the fresh remains odor with no false positives. These results indicate that the odors from the STU-based training aids are recognizable to trained canines. However, the concentration of odor and the packaging of the training aids need to be examined further.

3.1.1.2. Trial 2: collection methods

The number of scent pads and length of scent collection time was varied in an attempt to modify the amount of available odor on the scent pads. All canines positively alerted to all training aids and there were no false positives (Table 9). While this was a positive result for the use of STU-based training aids, it did not yield any additional information about the lower detection limits of the canines utilizing such aids.

3.1.1.3. Trial 3: life time of scent in open jars

When canine trials are being conducted, the time lapse between the start of the first canine run and the last canine run may be as long as several hours depending upon the number of canines being used, among other factors. It is important to confirm that the odor concentration of the scent source is still at a high enough level to be detected by the final canine, as well as the first.

At time zero, the five canines alerted to both of the training aids (Table 10). After 24 h, there were still three alerts to the training aids out of a possible six, a 50% rate of detection. There were no false positives during any run. To insure consistency in odor concentration for further canine trials, it was suggested that the jars not be left out for more than 12 h, which should be ample time to carry out a trial with many canines.

3.1.1.4. Trial 4: assortment of scent sources

It is important for HRD canines to be exposed to a diverse range of odors during training. Training aids were made from different odor sources listed in Table 11. All of the canines alerted to the scent pads were made from blood, fresh remains, and decomposition fluid (Table 11). Five of the eight canines alerted to the adipocere scent pad. The three canines that did not alert to the adipocere scent pads were the three novice canines. Two canines falsely responded to the blank, but no other false positives were made. These results show that the STU-100 can be used for the creation of training aids from any type of scent source.

Table 9
Canine responses to training aids in Trial 6.

Sample	Number of gauze pads	Length of collection (min)	Response
Decomp	1	1	6/6
Decomp	3	1	6/6
Decomp	6	1	6/6
Decomp	1	5	6/6
Decomp	1	10	6/6
STU blank	3	1	0/6
Gauze blank	–	–	0/24
False positives			0/30

Table 10
Canine responses to training aids in Trial 3.

Block #	Contents	Run 1 (0 h)	Run 2 (2 h)	Run 3 (12 h)	Run 4 (24 h)
2	Decomp 1	5/5	3/3	3/3	2/3
9	Decomp 2	5/5	3/3	2/3	1/3
Rate of detection		100%	100%	83%	50%
False positives		0/40	0/24	0/24	0/24

3.1.1.5. Trial 5: population study

A final set of field tests were carried out to assess canine response to a series of STU-100 based training aids packaged in both glass jars and aluminized bags placed in separate line-ups. The responses of twenty-six canines supervised by five different trainers/handlers were evaluated (Tables 12 and 13). In the case of the training aids in glass jars, eleven of the twenty-six canines alerted (one canine showed interest) to the training aid made from the freshly deceased body, and six alerted (one showed interest) to the aid made from the odor of decomposition fluid.

The positive predictive value (PPV) and negative predictive value (NPV) were calculated based on the canine responses listed in Table 12. The PPV and NPV values were calculated excluding the responses to the scent pads made from live human and animal remains because some forms of training or cross-training may consider a canine to alert to such odors correctly while others may not. The PPV for the training aids in the jars was 86%. In other words, 86% of the canine alerts were correct, and the other 14% were false positives. The NPV was 41%, meaning that 41% of the time a canine did not give a response, the non-response was correct. The chance a canine gives a correct positive alert (PPV) is based on the quality of the scent source (the training aids in question) and the training of the canine. The chance that a canine gives a correct non-response (NPV) could possibly be caused by the use of contaminated or ineffective training aids during the training process. A PPV of 86% indicates that odors from the training aids created in this study were reasonably recognizable to human remains canines.

Table 11
Canine responses to training aids in Trial 4.

Block #	Contents	Response
2	Blood	8/8
3	Fresh Remains	8/8
4	Decomp Fluid	8/8
5	Adipocere	5/8
6	STU blank	2/8
–	Gauze blank	0/24
False positives		2/32

Table 12
Results from population study; training aids in jars (A = Alert, I = Interest, 0 = No Response).

Handler	Canine	Blank	Live human	Chicken remains	Freshly deceased	Decomp fluid
Handler A	A1	A	0	0	A	A
	A2	0	0	A	A	A
	A3	A	0	A	0	0
	A4	0	0	0	A	A
	A5	0	0	0	A	A
Handler B	B1	0	0	A	A	0
	B2	0	A	I	0	0
Handler C	C1	0	0	0	0	0
	C2	0	A	0	0	A
	C3	0	A	0	0	0
	C4	0	0	A	0	0
Handler D	D1	0	0	0	0	A
	D2	0	0	0	0	0
	D3	0	0	0	0	0
	D4	0	0	0	0	0
	D5	0	0	0	A	0
	D6	0	0	0	0	0
	D7	0	0	0	0	0
Handler E	E1	0	0	0	A	I
	E2	0	0	0	I	0
	E3	0	0	A	A	0
	E4	0	0	0	0	0
	E5	0	0	0	0	0
	E6	0	0	0	A	0
	E7	0	0	0	A	0
	E8	I	0	0	A	0
Total	26	2(3)/26	2/26	5(6)/26	11(12)/26	6(7)/26

The training aids stored in the aluminized bags yielded poorer results compared to those stored in the glass jars. Only three canines alerted to the aids made from remains odor, compared to seven canines that alerted to the blanks. The PPV for this set of training aids was only 53% (NPV = 30%). This indicates that the odor was likely not fully contained inside the aluminized bags, allowing the scent to dissipate from the inside of the bags during storage or to modify the scent picture. The high number of positive responses to the blanks may indicate possible cross-contamination when the aluminized bags are stored next to one another.

The live human and animal remains odors were used as distracters as they may elicit responses from HRD canines cross-trained on live human scent or from novice canines. For the training aids stored in jars, only two canines alerted on the live scent, the same false positive rate as on the blank; however, five canines alerted on the chicken remains (three intermediate, two

Table 13
Results from population study; training aids in aluminized bags (A = Alert, I = Interest, 0 = No Response).

Handler	Canine	Blank	Live human	Chicken remains	Freshly deceased	Decomp fluid
Handler A	A1	0	0	A	0	A
	A2	0	0	0	0	0
	A3	0	0	0	0	0
	A4	0	0	0	A	0
	A5	0	0	0	0	0
Handler B	B1	0	0	0	0	A
	B2	A	A	0	0	0
Handler C	C1	A	0	0	0	0
	C2	A	0	0	A	A
	C3	0	0	A	0	0
	C4	A	0	0	0	A
Handler D	D1	0	0	0	0	0
	D2	0	0	0	0	0
	D3	0	0	0	0	0
	D4	0	0	0	0	0
	D5	0	0	0	0	0
	D6	0	0	0	0	0
	D7	0	0	0	I	0
Handler E	E1	A	0	I	0	0
	E2	0	I	0	0	0
	E3	A	0	0	0	0
	E4	0	0	A	0	0
	E5	0	I	0	A	0
	E6	0	A	0	0	0
	E7	0	0	A	0	0
	E8	A	I	0	0	0
Total	26	7/26	2(5)/26	4(5)/26	3(4)/26	4/26

expert). For the training aids stored in the aluminized bags, the numbers of alerts on both the living human and animal remains were less than the number of false positives on the blank. To prevent alerts on the generic odor of decomposition, as opposed to the odor of *human* decomposition, it is important to provide adequate training with appropriate storage conditions. Additional study is required to further optimize training aid type, storage and presentation techniques.

No significant differences were found between the responses of expert canines compared to the novice canines, as might have been expected. This indicates that the canines' responses to the training aids are possibly related to the manner of training and type of training aid used during training than the actual amount of training. For instance, Handler A is the only handler in the study that uses scent line-ups in regular training, and Handler A's canines gave the highest rate of positive responses to the remains training aids. Handler E also uses scent line-ups in training, but only in the beginning stages of training and for remedial work. These canines also gave a relatively high number of correct alerts. Other handlers only use line-ups occasionally or not at all. The previous familiarity of Handler A's and Handler E's canines with scent line-ups may be one reason their canines performed better on the tests.

The types of training aids used during regular training may have also affected the canine response. As mentioned previously, it is imperative that the quantity and type of scent source vary regularly during training. The available odor from the scent pads is relatively low compared to actual tissue or body parts. Canines that were already accustomed to lesser quantities of odor would likely perform better during these trials, compared to canines that have only been trained on large quantities of odor. Handlers A and C use a wide variety of scent sources and quantities, while Handler B only uses tissue, bones and body parts yielding greater amounts of available scent. Such differences may affect the canines' performances.

The previous trends are consistent with the SWGDOG best practice recommendations. In the Human Remains Detection document, SWGDOG recommends that both odor recognition tests (scent line-ups) and comprehensive assessments (training aids hidden or similar scenario) be used during training. SWGDOG also recommends that the types of training aids include a wide variety of human remains' odor sources and levels of decomposition [11]. Future research will help identify the components of training methods, training aids and testing protocols on the reliability measured.

When using the STU-100 based training aids, the amount of available odor could be easily increased and decreased by adding and removing scent pads. Thus, they have the potential to be used to improve canines' responses to lower quantities of odor. Additionally, the type of odor can be altered by collecting scent pads from various remains sources. To further improve and exploit the full potential of these training aids, canine handlers should incorporate the STU-100 based training aids into their regular training practice, followed by further testing of the canines.

4. Conclusions

The human remains detection canine community is in need of improved training aids that are easily and legally obtainable, non-hazardous, reusable, and representative of the entire odor picture of human remains. The training aids in this study were created in an attempt to fulfill the requirements currently demanded by HRD canine handler community using the STU-100 for the collection of human remains odor onto a gauze pad. The gauze pad containing the odor of interest was removed from the STU-100 and stored for later use as a canine training aid. Overall, the STU-100 based training aids showed great potential when tested with HRD canines, as the majority of canines responded correctly (nearly 90%) to the new training aids at different concentrations and from different odor sources in nearly every scenario tested with minimal false positives (typically below 10%).

This type of training aid can be created from any type of scent source, thus allowing for the diversity in training aid odor necessary to train a successful HRD canine. The lower limit of detection by a canine can be improved by using different amounts of available scent, which could also potentially be accomplished with these aids by changing the collection length and/or number of pads used. These training aids can be created by any police department, agency or university with access to an STU-100 or like device, then shipped to and stored by the canine handler with no legal, biohazard or disposal issues. Also, since these scent pads yielded reliable results with the canine teams and have simplified odor profiles compared to actual human remains, they are useful in focusing the signature chemicals for human remains detection. Because of the great potential for this type of training aids, further refinement of the generic training aid creation procedure and additional population study is expected to improve the success rate even further.

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