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Applied Animal Behaviour Science 98 (2006) 277–292
APPLIED ANIMAL BEHAVIOUR SCIENCE
www.elsevier.com/locate/applanim

Effects of training paradigms on search dog performance

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Accepted 3 August 2005
Available online 27 October 2005

Abstract

Performance of scent-detection dogs might be negatively affected when they have been trained to discriminate between scents according to a handler-issued verbal cue, compared to dogs trained to only locate one scent. The performance of scent-detection dogs trained to locate only live scent (live-only dogs) was compared to that of scent-detection dogs trained to locate either live or cadaver scent depending on the handler's verbal cue (cross-trained dogs). Specifically, it was predicted that live-only dogs would be more successful than cross-trained dogs at locating live scent when cadaver scent was present. Twenty-three dogs (11 live-only and 12 cross-trained) were given handler commands to search for live scent in four search areas containing different combinations of scent: no scent, live scent, cadaver scent, and live/cadaver scent. Each dog ran each search area twice. Live-only dogs had significantly more correct responses than cross-trained dogs in the no scent, cadaver scent, and live/cadaver scent search areas. There was no significant performance difference between live-only and cross-trained dogs in the live scent search area, confirming detection abilities of the cross-trained dogs when presented with only live scent. The ability of cross-trained dogs to correctly indicate the presence or absence of live scent according to a verbal cue was compromised when cadaver scent or no scent was present. This strongly suggests that cross-trained dogs should not be deployed where cadaver scent is present and the desired target is live scent, for example, a disaster deployment of search dogs to locate surviving victims amongst possible non-survivors.

Keywords: Dog; Discrimination learning; Olfaction; Scent detection

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0168-1591/$ – see front matter
doi:10.1016/j.applanim.2005.08.022

1. Introduction

Scent-detection dogs are dogs are trained to work in a variety of scent-detection situations, such as explosives, drugs, and snakes (Engeman et al., 2002; Williams and Johnston, 2002). One of the more critical scent-detection tasks for which dogs are trained is that of locating humans. One subset of human scent-detection dogs, referred to as "air scent dogs," does not require a scented article, tracks, or a start point (Syrotuck, 1972; ARDA, 1991). Air scent dogs search an area indicated by their handlers, offering some operant response (e.g., either remaining with the victim and barking to alert the handler, or returning to the handler and leading the handler back to the victim) if they detect the scent of any live individual within their search areas. Air scent dogs can seek out individuals in wilderness situations, hidden individuals in law enforcement scenarios, or buried victims on a disaster site. Another application of scent-detection dogs is the location of deceased humans. These dogs, known as "cadaver dogs," are conditioned to offer a specific operant response (e.g., lying down and barking) upon detecting human remains, including body fluids, decaying flesh, and blood (Rebmann et al., 2000).

Search dogs trained to detect one scent and perform a specific response upon locating that scent have learned a simple operant association, which can then be linked to other contextual cues, such as a particular collar or other canine garb worn for searching. However, dogs trained to detect two different scents depending on a verbal cue issued by the handler are performing biconditional operant discriminations, or multiconditional discriminations if more than two scents are each paired with unique commands. An example of a multiconditional discrimination is a law enforcement canine expected to do a building search for either a hidden individual, gun, or drugs based upon the verbal cue issued by the handler.

While laboratory demonstrations of biconditional discriminations have been successfully achieved in a variety of organisms such as rats (Honey and Watt, 1999), rabbits (Saavedra, 1975), and humans (Lober and Lachnit, 2002), successful execution of at least one biconditional discrimination problem occurring outside controlled laboratory conditions has not been evaluated. Specifically, search dogs are often trained using a biconditional discrimination paradigm to locate either live human scent or cadaver scent, depending on the verbal cue issued by the handler. These dogs are referred to as "cross-trained live/cadaver dogs" (CARDA, 2003). Such cross-trained dogs may be deployed in disaster situations, which typically involve overwhelming amounts of cadaver scent. A cross-trained dog is then expected to search exclusively for survivors among the rubble and potentially large numbers of dead victims, withholding a previously reinforced cadaver response over extended periods of time.

It is possible that requiring cross-trained dogs to perform biconditional scent discrimination according to verbal cues compromises their ability to indicate the presence of the trained scents to a degree that, while acceptable under laboratory conditions, is not acceptable in the applied, real-world disaster situation. Incorrect responses, either failure to indicate when a live victim is detected or falsely alerting when no live victim is present, could result in the tragic consequences of not rescuing a survivor or incorrectly diverting resources away from other areas, respectively.

In a disaster situation, a dog would encounter a scenario with one of four possible combinations of human scent: neither live nor cadaver scent (no scent), cadaver scent only (deceased victims), live scent only (survivors), or both cadaver scent and live scent. The present study examined whether cross-training negatively affects performance of search dogs in each of these four different possible combinations of live and cadaver scent. Given the potential confusion of the dog resulting from the requirement to withhold learned operant behaviors (responding to cadaver scent), the ability of live-only dogs to detect live scent was predicted to be better than that of cross-trained dogs when cadaver scent was present.

2. Animals, materials, and methods

2.1. Handler/search dog teams

A total of 23 handler/search dog teams participated in the present study. These teams were certified by an overseeing government agency (e.g., law enforcement) in either live-find only (live-only, $n = 11$), or both live-find and cadaver-find (cross-trained, $n = 12$). Additionally, the cross-trained dogs were trained to receive a different command to search for live versus cadaver. In support of the number of dogs used in the present study, previous studies using similar numbers of dogs have successfully identified significant differences (Hepper, 1988; Brisbin and Austad, 1991; Gagnon and Dore, 1993; Sommerville et al., 1993; Schoon, 1996; Slabbert and Rasa, 1997; Fiset et al., 2000). Groups of dogs from different training organizations in the Southwest and West Coast areas were tested as they became available, with every attempt made to keep the overall number of live-only and cross-trained dogs equal. Both live-only dogs and cross-trained dogs were represented in all areas. Search areas were comparable for all groups at their local testing sites.

2.2. Experimental design

The present study was designed to evaluate the hypothesis that the presence of cadaver scent would negatively affect the abilities of cross-trained dogs to detect live scent, compared to dogs only trained to detect live scent. In order to do this, live-only and cross-trained dogs were asked to search four small areas, representing the four possible combinations of live and cadaver scent, and indicate the presence of any live scent.

A 2×4 mixed factorial experimental design was used to test the proposed hypothesis. The independent variables were: (1) training paradigm, and (2) search scenario. The first independent variable, training paradigm, was a between-subjects variable with two levels: live-only and cross-trained. Random assignment of dogs into the two training conditions was not possible in this study, since dogs had been trained with different training methodologies. Dogs were classified as live-only or cross-trained according to the handlers' designations. In addition, handlers needed to be able to specify whether their dogs were issuing a live alert (indicating the presence of a live human) or a cadaver alert (indicating the presence of cadaver scent).

The second independent variable, search scenario, was a within-subjects variable with four levels: no scent, live scent, cadaver scent, and both live and cadaver scent. These levels of search scenarios were presented to the dogs in four separate search areas, each containing one of the four possible combinations of live and/or cadaver scent. Each search team did two searches in each of the four search areas, for a total of eight searches per team. Each search was a maximum of 5 min, and search order was counterbalanced across participants and search areas.

Each of the four search areas consisted of a similarly sized indoor area with actual search area layouts dependent on the nature of the building available for testing at the different locations. Search areas either consisted of a hallway approximately 2–5 m wide and 7–11 m long, with two to four doors along each side, or a single open room between 25 and 40 m^2. Victims were hidden in the live scent and live/cadaver search areas behind a barrier. This barrier was either a door, where the victim was sitting up against the door, or in one case, behind a hanging tarp.

Each search area also contained fifteen 90-ml sterile plastic specimen collection cups (Laboratory Specialists Inc.), used to hold cadaver scent in the two search areas utilizing cadaver scent (cadaver scent search area, live/cadaver scent search area). The lid on each cup had five holes of approximately 0.5 cm diameter drilled in it. Each cup contained one 5 cm × 5 cm cotton square that either had no scent or cadaver scent (described below).

The plastic cups were then concealed in two physically separated groups within the search area. One grouping consisted of 5 cups, and the other grouping consisted of the remaining 10 cups. The group of five cups was concealed within a closed corrugated cardboard 46.04 cm × 45.72 cm × 40.64 cm box. The group of 10 cups was located together behind and against the barrier. In each search area, the dog encountered the cardboard box containing the group of five cups, located within 3 m of the barrier, before encountering the barrier behind which the group of 10 cups was located. This ensured that the response of all dogs encountering cadaver scent after being given a verbal cue to locate live scent could be evaluated. Thus, the four search areas differed in the scents presented as follows.

1. No scent: This search area had no live scent and no cadaver scent. No live victim was hidden. No scent was applied to the cotton squares in the cups. The group of 10 cups was located behind the barrier, while the group of 5 cups remained in the cardboard box as described above.
2. Live-only scent: This search area had a hidden live victim. No scent was applied to the cotton squares in the cups. The group of 10 cups was located in close proximity to the live victim hidden behind the barrier, while the group of 5 cups remained in the cardboard box as described above.
3. Cadaver-only scent: No live victim was hidden. This search area had 0.5 ml of cadaver simulation scent (Sigma Pseudo-Corpse, St. Louis, MO, #P4304) applied to each cotton pad within each of the 15 cups. The group of 10 cups was located behind and up against the barrier, while the group of 5 cups remained in the cardboard box as described above.
4. Live and cadaver scent: This search area had both a hidden live victim, and 0.5 ml of cadaver simulation scent applied to each cotton pad within each of the 15 cups. The group of 10 cups was located in close proximity to the live victim hidden behind the barrier, to evaluate the effect on the dogs of locating live and cadaver scents together. The group of five cups remained in the cardboard box as described above.

Each of the four search areas was designated either “A”, “B”, “C”, or “D”. Prior to the start of testing, handlers were given a small card containing the randomly-assigned individual counterbalanced running order of their eight runs (two in each search area), identified by these letters. Handlers were given instructions to cue their dogs “to clear” each search area for the presence of a live victim; that is, to have their dog search each area only for the scent of a live victim, give the appropriate response and indicate the location of the victim if the scent was detected. Handlers were told that they would have 5 min to clear each area.

Each search area had one observer who was responsible for recording dog/handler search team response while the search team worked that search area. Observers were individuals with prior search dog experience. Prior to beginning each search, handlers would describe to the observer what their dogs' live and cadaver alerts were. Live alerts primarily consisted of the dog either standing in front of the live target and barking, or returning to the handler and then returning to the target and barking. Cadaver alerts primarily consisted of the dog either sitting or lying down in front of the cadaver target and barking. If the dog performed the behavior identified by the handler, the observer recorded both the behavior and the location of the dog at the time the alert was noticed.

The present study was a double-blind study; neither dog/handler teams nor observers knew which conditions were present in each search area. Thus, observers recorded dog alerts (as previously defined by each handler), without evaluation of the correctness of the alert. Because search areas were simple and limited in size, it was readily apparent when reviewing observations whether dogs were indicating at the correct location to identify the presence of a hidden victim.

The dependent variables were total number of successful responses of each dog in each search area. The score range for each search area was 0–2. Response errors were also recorded. The nature of a correct response and types of possible errors differed across search area (see Table 1). False alerts were alerts given by the dog in the absence of scent. A live false alert was an incorrect indication that a victim was present when no victim was present, or an incorrect indication of victim location if a victim was present. A cadaver false alert was an incorrect indication that cadaver scent was present when none was

Table 1
Correct response and possible error responses for each search area when instructions were to find a live victim

Search area	Correct response	Possible error responses
No scent	No alert	Live false alert Cadaver false alert
Live	Live alert	Live false alert Cadaver false alert No alert
Cadaver	No alert	Live false alert Cadaver alert
Live/cadaver	Alert on live	Live false alert Cadaver alert No alert

present. In those search areas containing cadaver (cadaver scent and live/cadaver scent search areas), a cadaver alert was recorded as an error, since the dogs had received a verbal cue to alert only on live scent. It was expected that only cross-trained dogs would issue cadaver alerts or cadaver false alerts.

Every effort was made to keep environmental variables such as airflow, temperature, humidity, and temperature constant by utilizing indoor testing areas. Efforts were also made to keep search area layouts as homogeneous as possible. However, the point of the present study was to determine whether cross-trained dogs were affected by the presence of one trained scent after receiving a verbal cue to locate a different trained scent, not to test the general search abilities of the participating teams. Therefore, search areas were small and searches were designed to be simple and straightforward. All victims and scent cups (including cups containing scent and those without scent) were placed in their hiding locations well before dogs started searching to permit generation of a scent pool surrounding the victims and the scent cups in their locations (Syrotuck, 1972). Victims were located up against each barrier, with an unobstructed airflow available at the bottom of each barrier to ensure maximum dispersal of their scent pool around the area of the barrier. Regardless of search area layout, dogs encountered the box containing the five cups prior to encountering the hidden victim. Moreover, the use of certified teams would have mitigated any effects of differing environmental and spatial conditions by ensuring that participants had previously met stringent requirements in demonstrating their abilities to perform searches under varying conditions. Counterbalancing running orders across search areas and participants at each location further ensured that conditions were balanced across all runs at each testing site.

2.3. Statistical analyses

A separate independent measures *t*-test (SPSS for Windows, Release 11.5.0) was used to compare performance of live-only and cross-trained dogs in each search area. Independent measures *t*-tests were also used to compare differences between live-only and cross-trained dogs and dog handlers, and analyze errors in each search area. A significance level of $p < 0.05$ was adopted to conclude statistical significance for the results.

3. Results

3.1. Sample description

This study used 23 search dog/handler teams to evaluate differences in performance between live-only ($n = 11$) and cross-trained ($n = 12$) dogs in four different search areas (no scent, live scent, cadaver scent, and live/cadaver scent). Each dog ran each search area twice, for a total of 46 runs per search area, or an overall total of 184 runs (46 runs per search area $\times$ 4 search areas). Of the 46 runs per search area, 22 runs were by live-only dogs and 24 runs were by cross-trained dogs.

Table 2 presents descriptive information regarding the dogs used in this study. The live-only dogs had a significantly lower mean age than cross-trained dogs [$t(21) = -2.252$, $p < 0.05$]. A total of nine different breeds participated, with Labrador Retrievers

Table 2
Dog sample descriptive statistics for live-only ($n = 11$) and cross-trained ($n = 12$) dogs

	Live-only		Cross-trained	
	Frequency	Percent	Frequency	Percent
Dog age (years)				
0–2	2	18.2	1	8.3
3–4	5	45.5	2	16.7
5–6	3	27.3	4	33.3
7–8	1	9.1	2	16.7
9–10	0	0.0	2	16.7
11–20	0	0.0	1	8.3
Total	11	100.0	12	100.0
Mean	2.27*		3.42	
Median	2.00		3.00	
Dog breed				
German Shepherd	3	27.3	1	8.3
Border Collie	0	0	4	33.3
Australian Shepherd	0	0	2	16.7
Golden Retriever	1	9.1	3	25.0
Labrador Retriever	5	45.5	0	0
Australian Cattle Dog	1	9.1	0	0
Belgian Malinois	1	9.1	0	0
Rottweiler	0	0	1	8.3
Dutch Shepherd	0	0	1	8.3
Total	11	100.0	12	100.0
Dog gender				
Male	5	45.5	6	50.0
Female	6	54.5	6	50.0
Total	11	100.0	12	100.0
Neutered				
Yes	10	90.9	11	91.7
No	1	9.1	1	8.3
Total	11	100.0	12	100.0

* Significant at $p < 0.05$ for live-only compared to cross-trained.

representing 45.5% of the live-only dogs and Border Collies representing 33.3% of the cross-trained dogs. Both genders were evenly represented in live-only and cross-trained dogs, with only two dogs sexually intact.

3.2. Overall mean performance comparisons across search areas

Overall, live-only dogs had significantly more correct responses than cross-trained dogs across all four search areas [$t(21) = 4.015$, $p = 0.001$]. When comparing performance in individual search areas, live-only dogs performed significantly better than cross-trained dogs in three out of four search areas (see Fig. 1). Specifically, as predicted, live-only dogs

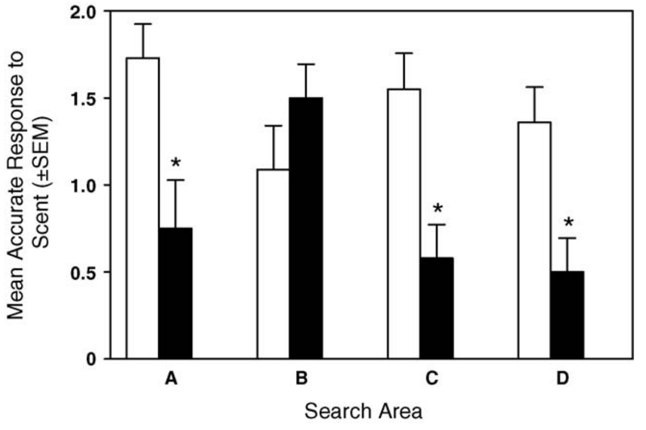

Fig. 1. Mean accurate responses of live-only dogs (open bars) ($n = 11$) and cross-trained dogs (solid bars) ($n = 12$) in each search area (A = no scent; B = live scent; C = cadaver scent; D = live/cadaver scent). Each search area was run twice by each team. *Significantly different from dogs using alternate training paradigm in same search area.

had a greater number of successful responses (refer to Table 1) than cross-trained dogs on the cadaver scent search area [$t(21) = 3.401$, $p = 0.003$] and live/cadaver scent search area [$t(21) = 3.069$, $p = 0.006$]. In addition, live-only dogs had more successful runs than cross-trained dogs on the no scent search area [$t(21) = 2.824$, $p = 0.01$]. There was no significant difference in performance between live-only and cross-trained dogs in the live scent search area.

3.3. Successful runs

A summary of number of successful runs and success rates for each group of dogs in each search area is presented in Table 3. Out of the total of 184 runs over four search areas by the 23 dogs (11 live-only, 12 cross-trained), 103 runs (56%) were done with the dog issuing the appropriate response in the four different search areas. Live-only dogs had over

Table 3
Summary of search results comparing number of successful runs and success rates for live-only (LO) dogs ($n = 11$, total possible correct runs for each search area = 22) with cross-trained (XT) dogs ($n = 12$, total possible correct runs for each search area = 24)

Search area	# Successes		Success rate	
	LO	XT	LO (%)	XT (%)
No scent	19*	9	86	38
Live	12	18	55	75
Cadaver	17**	7	77	29
Live/cadaver	15**	6	68	25
Total	63*	40	72	42

* Significant at $p < 0.05$ for live-only compared to cross-trained.
** Significant at $p < 0.01$ for live-only compared to cross-trained.

twice as many correct runs than cross-trained dogs in the no scent, cadaver scent, and live/cadaver scent search areas. Although live-only dogs did significantly better than cross-trained dogs in these search areas, the best success rate for live-only dogs was in the no scent search area, followed by the cadaver scent search area, the live/cadaver search area, and their lowest success rate in the live scent search area. Contrary to this, cross-trained dogs had their best success rate in the live scent search area, followed by the no scent search area, the cadaver scent search area, and their worst performance in the live/cadaver scent search area.

3.4. Analysis of dog errors

A breakdown of errors in each search area (see Table 1 for possible errors in each search area) was done to determine whether cross-trained dogs were being distracted by the presence of cadaver scent in the cadaver and live/cadaver search areas. Errors occurred in 81 out of the total 184 runs over four search areas (see Table 4). Overall, dogs made the most errors in the live/cadaver scent search area and the cadaver scent search area; fewer errors occurred in the no scent search area and the live scent search area. Types of errors varied according to search area.

In the no scent search area, errors included live false alerts and cadaver false alerts. Live-only dogs had two live false alerts and one cadaver false alert; cross-trained dogs had seven live false alerts and eight cadaver false alerts. It was unexpected to have a handler that

Table 4
Summary of search errors and error rates comparing live-only (LO) dog errors to cross-trained (XT) dog errors in all search area

Error type	Errors		
	LO (%)	XT (%)	Total (%)
No scent search area			
Live false alert	2 (9)	7 (29)	9 (20)
Cadaver false alert	1[a] (5)	8 (33)	9 (20)
Live scent search area			
Live false alert	1 (5)	0 (0)	1 (2)
Cadaver false alert	1 (5)	5 (20)	6 (13)
No alert	8* (36)	1 (4)	9 (20)
Cadaver scent search area			
Live false alert	4 (18)	3 (13)	7 (15)
Cadaver alert	1** (5)	14 (58)	15 (33)
Live/cadaver search area			
Live false alert	0 (0)	2 (8)	2 (4)
Cadaver alert	2[a] (9)	7 (29)	9 (20)
No alert	5 (38)	9 (38)	14 (30)
Total errors	25 (28)	56 (58)	81 (44)

[a] Significant at $p < 0.05$ if live-only cadaver indication is removed.
* Significant at $p < 0.05$ for live-only compared to cross-trained.
** Significant at $p < 0.01$ for live-only compared to cross-trained.

presented a dog as a live-only dog describe that dog's behavior to the observer as a cadaver alert; possible explanations and potential ramifications of this are offered in the Section 4. However, if the live-only dog that issued the erroneous cadaver false alert is removed from the analysis, cross-trained dogs had significantly more cadaver false alerts than live-only dogs [$t(20) = -2.365$, $p < 0.05$]. Importantly, although it seems obvious that only cross-trained dogs would issue cadaver false alerts, this finding emphasizes that cross-trained dogs have an opportunity to make a mistake that live-only dogs do not, and that they make this mistake frequently enough to achieve statistical significance.

In the live scent search area, possible errors were live false alerts, cadaver false alerts, and no alerts. Live-only dogs had significantly more no alerts than cross-trained dogs, [$t(21) = 2.653$, $p < 0.05$], even though live scent was present. Again, unexpectedly, in this scenario, one live-only dog issued a cadaver false alert.

In the cadaver scent search area, errors recorded were live false alerts and cadaver alerts. There were no cadaver false alerts, based on dogs' proximity to scent. Cross-trained dogs had significantly more cadaver alerts than live-only dogs [$t(21) = -4.033$, $p = 0.001$], again demonstrating that the presence of cadaver scent was significantly affecting performance of cross-trained dogs. The difference in number of live false alerts was not significantly different between live-only dogs and cross-trained dogs.

In the live/cadaver scent search area, errors observed were live false alerts, cadaver alerts, and no alerts. There were no cadaver false alerts, based on dogs' proximity to scent. Again, there was no significant difference between live-only and cross-trained dogs for live false alerts. However, if the live-only dog that issued two erroneous cadaver alerts is removed from the analysis, cross-trained dogs then issued significantly more cadaver alerts than live-only dogs [$t(20] = -2.317$, $p < 0.05$]. In addition, although not significantly different, live-only dogs had less than half the no alerts of cross-trained dogs.

3.5. Inconsistent individual dog responses

Because each dog ran each search area twice, it was possible to measure inconsistency of individual dog responses in each search area. Possible combinations for each set of two runs in a search area are two correct responses, two incorrect responses, or one correct response and one incorrect response. Thus, dogs with either two correct or two incorrect responses in a search area are not reflected in these measurements.

There were 92 sets of two runs in each search area (4 search areas × 23 dogs). Of these 92 sets, overall responses of dogs were inconsistent between the first and second runs in 32 sets (35%) (Table 5). The no scent search area had the fewest inconsistent sets. There were 150% more inconsistent sets in the live/cadaver search area than in the no scent area, and 125% more inconsistent sets in the live scent search area and in the cadaver scent search area than in the no scent area.

4. Discussion

The purpose of the present study was to assess whether training scent-detection dogs to locate more than one scent based on a handler's verbal cue would affect the ability of the

Table 5
Summary of inconsistent responses and inconsistent response rates between the first time and the second time a search area was run for live-only (LO) dogs ($n = 11$) and cross-trained (XT) dogs ($n = 12$)

Search area	Inconsistent responses		
	LO (%)	XT (%)	Total (%)
No Scent	1 (9)	3 (25)	4 (17)
Live	5 (45)	4 (33)	9 (39)
Cadaver	3 (27)	6 (50)	9 (39)
Live/cadaver	5 (45)	5 (42)	10 (43)
Total	14 (32)	18 (38)	32 (35)

search dogs to correctly locate and indicate the cued scent. Specifically, it was predicted that cross-trained dogs would perform significantly worse than live-only dogs when given a verbal cue to search for live scent in search areas containing either cadaver scent alone or a combination of cadaver scent and live scent. As predicted, the ability of cross-trained dogs to detect and indicate the presence of live scent was significantly below that of live-only dogs when cadaver scent was present, either alone or in combination with live scent. Additionally, contrary to prediction, cross-trained dogs had significantly fewer correct responses than live-only dogs when neither cadaver nor live scent was present. Although cross-trained dogs had more correct responses than live-only dogs when only live scent was present, the difference was not significant. The most parsimonious explanation for degraded performance of cross-trained dogs is either the nature of the problem or the training process, or some combination of these factors.

Dogs trained on a single scent learn a simple association consisting of a fixed contingency between a stimulus element (one trained odor or group of odors) and reinforcement for performing an operant behavior (alerting) upon detection of the stimulus element. When search dogs are cross-trained, they must develop an understanding of the relationships between different stimuli (live scent, cadaver scent, and the verbal cue for each) and their individual reinforcement contingencies. Both odors present together effectively provide the dog with a compound stimulus consisting of the separable elements of live odor and cadaver odor, along with the stimulus unique to the combination of live and cadaver odors (Rescorla, 1973).

The paradigm faced by a cross-trained dog is, therefore, a biconditional discrimination problem, where each possible element would be reinforced 50% of the time if equal presentations of scents and verbal cues were offered in training (Saavedra, 1975). This biconditional discrimination problem is an example of a configural association, where stimulus elements bear some specific relationship to each other that defines reinforcement contingencies (Sutherland and Rudy, 1989). Cross-trained dogs must not only construct representations of the individual cues, odors, and operant responses; they must maintain relationships between configural and simple associations. Although dogs have displayed the ability to condition to various combinations of such configural situations (e.g., Woodbury, 1943), simple discriminations are more rapidly and reliably learned than compound discriminations, in part because they are mediated by different neurological systems (Sutherland and Rudy, 1989). For example, although unnecessary for simple association learning, the hippocampus and cortical cholinergic system have been demonstrated as essential for many facets of configural learning (Sutherland and Rudy, 1989; Dusek and Eichenbaum, 1998; Butt and Bowman, 2002; Larson and Sieprawska, 2002).

Thus, simply learning to discriminate live scent and cadaver scent separately will not necessarily generate configural solutions when faced with the configural problem presented by the presence of both (Alvarado and Rudy, 1992). Elemental solutions are generally preferred (Saavedra, 1975; Williams et al., 1994), as supported by the results of cross-trained dogs in both the cadaver scent and live/cadaver search areas, where cross-trained dogs alerted incorrectly on the cadaver scent on 21 out of 48 runs. These cross-trained dogs appeared to be using an elemental solution to a configural problem, performing simple scent discrimination rather than solving a discrimination problem based on the verbal cue issued by the handler. The cadaver/live search area in particular was specifically designed to emulate the conditions found in a disaster; that is, cadaver scent and live scent were present concomitantly. Performance of cross-trained dogs was the poorest in this search area, with dogs were equally likely to correctly alert on the victim, alert on the cadaver, or to issue no alert at all. It is possible that finding cadaver and live scents together was so confusing that the dogs simply refrained from alerting rather than attempt to solve the mixed configural problem presented. It is also possible that the combination of live and cadaver scent represented a compound scent (a configural stimulus) that was not associated with any previous reinforcement.

Moreover, the requirement for cross-trained dogs to withhold a trained operant response to the uncued odor, if present, represents a variant of discrimination-reversal learning (Klein, 2002). Withholding response to a previously reinforced cadaver stimulus represents a highly advanced cognitive function, involving the prefrontal cortex, parietal lobe, and temporal lobe (Rubia et al., 2003). Also, ventral striatal neurons display firing selectivity in response to odors predictive of appetitive outcomes, and reverse firing selectivity when odor-outcome contingencies are reversed (Setlow et al., 2003). These factors possibly contributed to difficulty of cross-trained dogs in this study to withhold responding to previously rewarded cadaver odor. It is also possible that the salience of odors exceeds that of verbal cues, perhaps due to the preferential access that the olfactory system has to brain structures involved in learning and memory (Larson and Sieprawska, 2002). It is further possible that the salience of the cadaver scent exceeds that of live human scent, enhancing difficulty of cadaver scent response inhibition.

In the no scent search area, which represents the no go element of a go/no go problem, cross-trained dogs issued either a false cadaver alert or a false live alert in 15 out of 24 runs. Because this search area was included as a negative control, the tendency of cross-trained dogs to alert when no scent is present suggests a potentiated tendency to alert. While there may have been trace amounts of live scent present in this condition, it was more probably due to insufficient training in no scent scenarios, inadvertent handler cuing arising from belief that some scent may be present, (undesired) olfactory conditioned response to some component in live and/or cadaver scent, or some combination of these factors. The potentiated tendency to alert suggests that training and certification, particularly for cross-trained dogs, should include a measure to evaluate the ability of a search dog to perform effectively in a no scent scenario.

Unexpectedly, there were two cadaver false alerts and three cadaver alerts made by live-only dogs. While statistics were presented both with and without these dogs included, this data was presented because it demonstrates an important issue in actual disaster deployment of search dogs. These alerts were made by dogs whose handlers presented them to the study as alerting on live scent only. Because this study utilized manufactured pseudo-scent that mimics the odor of human decomposition, it is unlikely that the dogs were recognizing some component of live human in the cadaver scent. What is more likely is that the dogs had been "exposed," that is, trained to alert on cadaver scent to some limited degree. Because the smell of pseudo-scent (e.g., decomposition) is particularly salient, it appears that even limited exposure to training with cadaver scent generates a rapid associative response in dogs. Previous reinforcement for cadaver scent, no matter how limited, appears to compromise performance, making it more difficult for a dog to ignore cadaver scent. This further increases the requirement that handlers understand how cross-training dogs will negatively impact reliability in an actual disaster deployment. The present study strongly suggests that dogs deployed in a disaster situation to find live victims should not be trained, even minimally, to alert on cadaver scent.

There are some situations where a cross-trained dog is mandatory, for example, the wilderness search situation. In this case, the victim may be alive or dead, and the dog needs to detect the victim and indicate the find to the handler. It is suggested that in this case, the dog should be trained to alert on either live or cadaver scent; that is, on a learning set of scents. Dogs, capable of developing learning sets consisting of at least 10 scents in a controlled environment (Williams and Johnston, 2002), are not asked to discriminate between different scents within that learning set. By grouping live scent and cadaver scent into a learning set when working a cross-trained dog, the need to solve a configural problem is eliminated. Such a dog, however, would not be able, nor should this dog be expected, to discriminate the presence of one of these scents while withholding response to the presence of the other.

An interesting finding was that responses of dogs differed between the first and second runs on 32 out of 92 sets (35%) of two runs on the same search area. Although the American Kennel Club requires repeated successful performances to receive obedience titles (American Kennel Club, 2003), search dogs are only required to have a single successful trial in order to become certified (Canine Working Group, 2003). The results of this study suggest that repeated successful performance should be demonstrated for search dog certification.

When data from this study are considered as a whole, overall dog success rate of 56% mirrors that of other scent-detection canines evaluated under double-blind conditions (e.g., Schoon, 1996; Engeman et al., 2002). It is possible that search dogs are relying on inadvertent, subtle human cues more than previously realized (Hare and Tomasello, 1999; Pongracz et al., 2001; Soproni et al., 2001; Soproni et al., 2002; Miklosi et al., 2003; Wells and Hepper, 2003; Gacsi et al., 2004). Such reliance on inadvertent social cues apparently affected both cross-trained and live-only dogs. Live-only dogs had 13 no alerts in the live scent search area and the live/cadaver scent search area. This represents 13 live victims that might have gone undetected in a real-life scenario. The results of this study suggest that training and evaluation measures include more double-blind trials where no humans present know the location of the hidden victim, particularly since dogs can recognize social cues, both verbal and nonverbal, from unfamiliar humans as well as their handlers (Pongracz et al., 2004; Fukuzawa et al., 2005). Training scenarios should also be designed so that during training, the handler can see the dog but the dog cannot see the handler. These measures would help eliminate the possibility that dogs are using subtle human cues to locate hidden victims or issue alerts in training and evaluation.

Although 45.5% of live-only dogs were Labrador Retrievers and 33.3% of cross-trained dogs were Border Collies, it is unlikely that breed differences contributed to the differences in performance between live-only and cross-trained dogs. Border Collies have previously been rated as less distractible than Labrador Retrievers when searching (Rooney and Bradshaw, 2004). In addition, the ability of dogs to be influenced by human cues is breed-independent (Pongracz et al., 2005). This suggests that difficulties encountered within the configural situation presented in this study arise from the nature of the problem, rather than the breeds used.

It is also possible that the degraded performance of the cross-trained dogs was a result of inadequate training or variability in training methods and evaluation standards (Schilder and van der Borg, 2004). Further research would be required to determine if training dogs to initially recognize and alert to both scents as a learning set and subsequently attempting to place individual elements of the learning set under control of different cues provides better success than training dogs to perceive one signal as ‘‘search for and alert to live human’’ and another signal as ‘‘search for and alert to cadaver scent.’’ Initial elemental training interferes with later configural problems, when compared to initial configural learning (Melchers et al., 2005). Even with controlled training, however, reliability rates for configural problems rarely meet those obtained when performing a simple operant association (e.g., Alvarado and Rudy, 1992; Honey and Watt, 1999; Larson and Sieprawska, 2002). The enhanced noise and distraction provided by an applied canine working situation would be expected to further negatively impact performance (Maes and deGroot, 2002). Because the search task in a disaster situation is time-critical, dogs deployed in such a situation should be trained in a manner that ensures maximum reliability and minimizes the possibility that valuable resources will be inappropriately allocated as a result of an erroneous canine alert.

5. Conclusions

The main finding of this study was inferior performance of cross-trained dogs compared to live-only dogs when either cadaver scent or no scent was present. The differences in performance resulted from an inability of cross-trained dogs to utilize configural solutions for configural problems, a potentiated tendency of cross-trained dogs to alert when no scent was present, and, perhaps, an overreliance on subtle human cues.

These results strongly suggest that cross-trained (live/cadaver) dogs should not be deployed in a search situation where only live victims are sought, for example, a disaster scenario. These results also emphasize the need for trainers to carefully consider the complex learning paradigms and cognitive concepts underlying the tasks faced by search dogs in order to ultimately improve search dog performance.

Acknowledgements

This study was funded by a grant from ASI at California State University. L. Lit would like to offer thanks to her thesis committee members, Dr. John Clapper and Dr. Sanders McDougall, and especially, her chairperson, Dr. Cynthia Crawford, for untiring support of this research concept and its execution. The authors would like to gratefully acknowledge the handlers and dogs that participated in this research, and the many others that were critical for the successful running of this study. We would especially like to thank Debby Boehm, Holly Howell, and Paula O'Brien for their assistance. In addition, we would like to acknowledge Dr. Anita Oberbauer, for her insight and guidance with this manuscript.

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