DUTY CYCLE OF THE DETECTOR DOG:
A BASELINE STUDY

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EXECUTIVE SUMMARY

Dogs have been successfully used for many years by military and law enforcement agencies to detect varied substances. A 1991 report prepared for the US Congress noted that the dog and handler team remains the most widely used, accurate, durable and flexible system available for detecting illegal drugs and explosives (Technology Against Terrorism). Each year, the Department of Defense, federal, state and local law enforcement agencies spend considerable resources to breed, raise, purchase, train and maintain working dogs (Department of the Army, 1991; US Congress General Accounting Office, 1996). Although each agency may require different standards of their dogs, the ultimate goal for the departments is for every detection dog to optimally perform the task for which it has been trained. A critical aspect of canine performance is its effective duty cycle.

The phrase "duty cycle" refers to the period of time for which an instrument can be continuously used without deleterious effects in its operation (Duty Cycle, 1996). Although the phrase is usually used to describe the working cycle of mechanical instruments and technology, the concept can also apply to canines. As a detection instrument, the dog can also be evaluated in terms of its duty cycle. Thus applied, the duty cycle of the detection dog refers to the amount of time the dog will work without observed deterioration in its detection performance.

Current definitions of detection dog duty cycles are grounded in tradition and practical experience. Within the canine detection community, the most frequently stated duty cycle is 30 minutes. This definition seems to be the product of informal observations related to decreased search activity or willingness to work with little or no reference to detection performance, i.e., hits, misses and false alarms. In some instances, search activity and willingness to search are partly a product of training. Many canine personnel know that dogs can be trained to work for substantially longer periods without significant breaks, however, through tradition, the 30 minute work period seems to have become part of standard practice for many canine programs. Given the necessary training, conditioning, and maintenance, it is possible that dogs will work longer than 30 minutes.

Consideration of the detector dog's duty cycle raises definitional issues, however. Exactly what aspects of detection performance are involved in determining the duty cycle of detector dogs? Most handlers might say that there is no choice but to end the search when the dog is no longer willing to engage in active searching. The dog might fail to respond to handler prompts to sniff, engage in off task behavior, or simply slow down to the point that little progress is being made. On the other hand, some dogs might continue to search for extended periods, albeit less enthusiastically, but fail to perform as well as they did initially. For example, they might increasingly miss known targets or offer false alerts. In practice, handlers collectively use a variety of criteria, often informal, for deciding that a dog is no longer able or willing to work. In other words, no one feature or aspect is solely used to determine the duty cycle of the detector dog. It is apparent, then, that more than one dimension defines the duty cycle. Not only is the duty cycle defined by actual detection performance, hits, misses, false alarms, but also by rate of searching and willingness to search.

Additionally, each of these dimensions can be influenced by environmental conditions, such as ambient temperature and humidity, and characteristics of the site to be searched. Many environmental variables may contribute to performance deterioration or adversely affect detection performance. For example, one could assume that the duty cycle of a dog searching in hot weather might be shorter than it would be in cooler conditions. Similarly, it may be the case that high humidity affects effective working duration. As well, given strenuous exercise, a dog's body temperature increases, which may lead to deterioration in detection performance. Elements of training, such as number of targets per time searched, rate of reinforcement, and duration of search training, may also affect the duty cycle. Examining the relationship between such factors and detection performance may also contribute to the definition of the detection dog duty cycle.

This effort was designed as a descriptive study of canine detection performance that examined behavioral and physiological measures of the dog, and events providing the context for detection activities.

This study trained four dogs to detect two target odors. They were then deployed into various detection scenarios, under different environmental conditions, and many behavioral and physiological measures thought to be pertinent in determining the duty cycle of the detection dog were recorded. Data were collected for 12 months (230 work days with 751 searches) and then compiled and analyzed to determine if any variables contributed to or adversely affected the detection performance of these dogs.

Data show that, within the context of the study, the effective duty cycle under moderate environmental conditions was at least 91-120 minutes of continuous searching. Data show that elapsed search time and total search duration were weakly related to number of false alarms, trends expected, given that as search time increases, the opportunity to emit false alarms increases. Data also show that elapsed search time, total search duration, and search order were not directly related to probability of detection.

Data also show that, within the context of the study, environmental and physiological variables were not strongly related to duty cycle measures. Two of the four dogs showed a statistically significant negative relationship between percent hits and environmental temperature, and one dog showed a statistically significant positive relationship between percent hits and body temperature. No correlations between performance and relative humidity were statistically significant. However, this study could not address more extreme conditions, which may effect dog performance, than that afforded by the prevailing climate of Auburn, Alabama.

In sum, data show that all four dogs were willing and able to work as long as asked: In other words, the dogs did not provide their own limits. The conditions of this study did not exceed the capabilities of the dogs to work for extended periods, suggesting that, within practical limits, dogs will work for extended periods of time if they are trained to do so.

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1.0 Title

Duty cycle of the detector dog: A baseline study

2.0 Background

2.1 Introduction

Dogs have been successfully used for many years by military and law enforcement agencies to detect varied substances. A 1991 report prepared for the US Congress noted that the dog and handler team remains the most widely used, accurate, durable and flexible system readily available for detecting illegal drugs and explosives (Technology Against Terrorism). Each year, the Department of Defense, federal, state and local law enforcement agencies spend considerable resources to breed, raise, purchase, train and maintain working dogs (Department of the Army, 1991; US Congress General Accounting Office, 1996). Although each agency may require different standards of their dogs, the ultimate goal for the departments is for every detection dog to optimally perform the task for which it has been trained. A critical aspect of canine performance is its effective duty cycle.

2.2 Duty Cycle

The phrase "duty cycle" refers to the period of time for which an instrument can be continuously used without deleterious effects in its operation (Duty Cycle, 1996). For such an instrument, maintenance periods may be required to ensure quality performance; maintenance for a mechanical instrument might involve calibrating sensors, recharging or replacing batteries, etc. Although the phrase is usually used to describe the working cycle of mechanical instruments and technology, the concept can also apply to canines. As a detection instrument, the dog can also be evaluated in terms of its duty cycle. Thus applied, the duty cycle of the detection dog refers to the amount of time the dog will work without observed deterioration in its detection performance.

Current definitions of detection dog duty cycles are grounded in tradition and practical experience. Within the canine detection community, the most frequently stated duty cycle is 30 minutes. This definition seems to be the product of informal observations related to decreased search activity or willingness to work with little or no reference to detection performance, i.e., hits, misses and false alarms. In some instances, search activity and willingness to search are partly a product of training. Many canine personnel know that dogs can be trained to work for substantially longer periods without significant breaks, however, through tradition, the 30 minute work period seems to have become part of standard practice for many canine programs. Given the necessary training, conditioning, and maintenance, it is possible that dogs will work longer than 30 minutes.

Consideration of the detector dog's duty cycle raises definitional issues. Exactly what aspects of detection performance are involved in determining the duty cycle of detector dogs? The beginning of a single period of searching is clearly marked by the handler's

command to initiate search behavior, but what about the dog's behavior defines the end of the period, assuming that the search task itself is infinitely long? Most handlers might say that there is no choice but to end the search when the dog is no longer willing to engage in active searching. The dog might fail to respond to handler prompts to sniff, engage in off task behavior, or simply slow down to the point that little progress is being made. On the other hand, some dogs might continue to search for extended periods, albeit less enthusiastically, but fail to perform as well as they did initially. For example, they might increasingly miss known targets or offer false alerts. In practice, handlers collectively use a variety of criteria, often informal, for deciding that a dog is no longer able or willing to work. In other words, no one feature or aspect is solely used to determine the duty cycle of the detector dog.

It is apparent, then, that more than one dimension defines the duty cycle. The duty cycle is not only defined by actual detection performance, (hits, misses, and false alarms) but also by rate of searching and willingness to search.

Additionally, each of these dimensions can be influenced by environmental conditions, such as ambient temperature and humidity, and characteristics of the site to be searched. Many environmental variables may contribute to performance deterioration or adversely affect detection performance. For example, one could assume that the duty cycle of a dog searching in hot weather might be shorter than it would be in cooler conditions. Similarly, it may be the case that high humidity affects effective working duration. As well, given strenuous exercise, a dog's body temperature increases, which may lead to deterioration in detection performance. Elements of training, such as number of targets per time searched, rate of reinforcement, and duration of search training, may also affect the duty cycle. Examining the relationship between such factors and detection performance will contribute to understanding the variables influencing the effective working duration of detector dogs in order that their duty cycle may be better defined.

3.0 Objective

The primary objective of this project was to examine factors related to the duty cycle of the detection dog.

4.0 Method

4.1 Approach

This effort was designed as a descriptive study of canine detection performance that examined behavioral and physiological measures of the dog, and events providing the context for detection activities. The effects of any particular variable on dog performance can not be explicitly determined in this study, as this would require an experiment in which all variables except the one of interest are held constant. Rather, the extent (i.e., correlation) to which changes in particular variables were related to changes in dog performance are described (e.g., temperature vs. hit rate).

The primary question guiding the development of protocols concerned the duty cycle of the detector dog. The study involved designing a number of protocols associated with canine detection work, implementing those protocols over a 12-month period, and concurrently measuring a variety of variables. However, many other issues required attention as well. In order to insure useful generality of the findings, it was important to consider the typical deployment of detector dogs across various agencies and missions. A variety of contextual factors were also considered, including weather and factors associated with detection settings (Appendix A). Finally, as a study that would probe the limits of dogs doing detection work, it was important to assure the health of the dogs (Animal Welfare, 1994).

4.2 Dogs

Four dogs served throughout the 12-month period of testing. The dogs were housed in individual runs in the kennels maintained by the College of Veterinary Medicine at Auburn University (two of the dogs were housed together in a double-wide run for about two months in the summer). They were transported in individual air transport carriers mounted in a 1996 Ford Econoline van in a manner that met with USDA requirements for transport of dogs (Animal Welfare, 1994). Dog ages at the beginning of the study ranged from 13-24 months.

The dogs used in the study were selected so as to represent the breeds commonly used in law enforcement and were obtained in ways comparable to those of real-world procurement. The study examined the duty cycle of 4 dogs: one Dutch Shepherd (Booga), one Belgian Malinois (Marco), and two Labrador Retrievers (Sam & Sadi). Also, the dogs selected for the study varied in detection work experience, allowing for data obtained to be generalized to detection dogs with diverse training backgrounds.

4.3 Handlers

Throughout the course of the study, five research assistants served dog training and handling functions. All of these individuals held baccalaureate degrees, four in psychology and one in zoology. All had previous experience at Auburn University's Institute for Biological Detection Systems (IBDS) training and handling dogs, as well as instruction in behavior analysis. All handlers received training and instruction from Bob and Dr. Marian Bailey, prominent behaviorists in the field of animal training. Additional training and instruction was provided by Mr. Ed Hawkinson, at the time director of the US Secret Service Canine Program, who served as a consultant for IBDS personnel during the course of the project. Handlers also had opportunities to observe and receive instruction from other law enforcement personnel.

4.4 Odor Source Material and Delivery

The objective of this project focused on how long dogs were willing and able to work effectively in detection scenarios. Although the nature of target odor(s) is certainly relevant to how well dogs work, the study required only that odor source materials yield reasonably consistent vapor signatures. This criterion reduced the likelihood that

variations in performance from day to day would be substantially influenced by variations in the vapor characteristics of different target odors. Perhaps more importantly, the logistics of the project dictated that training aids not raise issues of safety or security. Due to large training area, close proximity of people, and concerns regarding control of illicit or detonable material, the project team elected to utilize benign training aids.

The primary odor source materials used throughout the project were geraniol (rose oil) and Dimethyl thiazole (a sulfur-based compound). Previous experience in training dogs to detect these compounds showed that they were readily detectable by dogs and could be prepared in quantities that were not readily detected by humans unless they sniffed the training aid directly (Johnston et al., 2000).

These compounds were used as training aids by placing designated amounts of the substance in permeation tubes. The cap at one end of these stainless steel tubes (14.5 cm long by 1.2-cm diameter) could be pulled out 2.5 cm exposing three 1-cm long openings that allowed vapor to escape (see Appendix C).

Stainless steel tubes were prepared weekly, during which clean gloves were always worn. Preparation began with the following steps: new viton O-rings were installed on the end caps, a small amount of cotton was inserted in the tubes, the odor material (1 ?l-1 ml) was applied to the cotton, another piece of cotton was inserted in the tube and the end caps were installed. Cleaning of the tubes involved removing the end caps from the tubes and discarding the cotton and the O-rings used to seal the tubes. The tubes were first rinsed with methanol and then with acetone. Finally, the tubes were heated at 140? C for a minimum of 4 hours. Typically, tubes were cleaned on Friday, left in the oven until Sunday, and prepared either Sunday evening or Monday morning. The amount of odor material that was placed in the tubes changed four times through the course of the study. However, the amount in the tubes was kept constant each week until an increase or decrease in amount was deemed necessary. These changes were made in order to identify an amount appropriate for the dogs' detection capabilities.

To avoid cross-contaminating the two different types of odors and differentially contaminating one type of odor tube, all tubes were treated in the same manner. They were stored in small plastic storage containers according to the material they contained. New gloves were used to open a container and another pair of gloves was used to remove a tube from the container. Beyond the standard procedures for avoiding contamination, a policy of changing gloves or cleaning tubes upon the recognition of any event that might have produced contamination was implemented.

To demonstrate stimulus control by the appropriate odors, blank tubes were routinely hidden during searches until approximately 7 months into the study. Because contamination possibilities are always a concern, one of the target tubes was lightly coated with Invisible Detection Powder (ACE Fingerprint Laboratories, Inc.) immediately after preparation. This is a light gray material that fluoresces under ultra-violet light. Following two days of use, inspection of the van and equipment used during

search scenarios revealed that this material was abundant in the environment. Therefore, it is possible that any blank tubes or non-targets placed were contaminated and their use was temporarily suspended.

Placement of blank tubes was resumed approximately one month later after the tube handling protocol was modified in the following ways to reduce the likelihood of cross-contamination. Only a third person who traveled to the site independently of the remainder of the team and used storage equipment and gloves that were not used by the other team members determined hide locations for blanks. This individual did not handle any materials used by the remainder of the team or interact with dogs. This was done as needed to demonstrate appropriate odor control. Because of the possibility of the blank tubes or the person hiding the tubes having been contaminated during the search this practice was done only during the first search session of the day. Blank tubes were cleaned prior to each such use.

4.5 Search Sites

The dogs were trained and tested in a variety of settings selected to reflect scenarios typical in the operational deployment of detector dog teams. Routine access to a total of 17 settings was obtained. The settings included the following types of environments: warehouse, residential, construction supply yard, football stadium, basketball coliseum, parking lots, open fields, university laboratories and classrooms, and industrial sites. To avoid odor contamination, a search site was used only once a week.

These settings collectively provided search scenarios with the following characteristics: outdoors, indoors, proximity to people and other animals, varied odors (including animal, food, chemical, and waste), noise, and density of materials to be searched. Search sessions were delineated according to the similarity of the search being conducted. Data were not collapsed across marked alterations in the characteristics of search sites regardless of physical proximity. For example, at the University's surplus property area, data were recorded individually for indoor and outdoor searches. As another example, data collected while searching the seating area of Beard-Eaves Memorial Coliseum was not collapsed with data produced from searching the concession areas of the coliseum.

4.6 Pretraining

Pretraining refers to training that occurred before the project's formal initiation and data collection protocol was begun. Over a period of approximately six months, the four dogs received varying amounts of training to work as detector dogs. It should be noted, however, that attaining good detection performance under typical field conditions did not require six months of daily training for these dogs. One dog began training only one month before testing and dogs were not routinely worked each day or even each week. This pre-training period coincided with other activities preparatory to data collection (e.g., acquiring dogs and equipment, establishing search sites, developing measures, and writing protocols), which did require six months to complete.

Pre-training involved limited obedience work, odor discrimination training for geraniol and Dimethyl thiazole, and search training under an increasing variety of placements in an increasing variety of settings. The initial training procedure was based on a combination of shaping and backward chaining. Initially, a tube was held within 15 cm of the dog's muzzle, "find it" was commanded, and the dog's behavior of touching the tube with its nose was reinforced. Using stimulus fading, this sequence was altered until the dog would walk down a fence line until contacting a partially hidden tube and then sit. From this point, the degree to which tubes were visible was decreased until alert responses were made based on odor alone. At this point, training in search scenarios began.

In this pretraining phase, all correct alerts were reinforced. Procedure for misses and false alerts entailed researching the area until the correct response was emitted. Training aid placement was determined by the individual collecting data and was not systematic. Typically these searches were short in duration and included only one target. However, a non-target odor, blank tube, or glove (i.e., a "clean" glove of the type used to handle tubes) was also frequently hidden to insure that the appropriate odor control was established.

As a study examining duty cycle, it was important to train dogs to work effectively as long as they were willing and able and then maintain that motivation throughout the year. The final training and deployment regimen were designed to assure that if dogs refused to work actively or began performing poorly it was not due to the way they had been trained but rather due to the prevailing physiological or environmental conditions. This involved paying special attention to a number of factors important in any type of search training such as, reinforcer efficacy, handler bias, use of blank hides, and number of target hides per time searched. As the study progressed, much was learned about accomplishing this training and these issues will be considered as part of the discussion section.

4.7 Test Sessions

The deployment protocol with its associated measurement procedures began in November 1998 and continued for 12 months. The purpose of this schedule was to allow each dog repeated exposure to all of the settings over a period of time sufficient to insure that all dog-setting combinations would be experienced multiple times under the full range of weather conditions available in Auburn, Alabama.

A search session was terminated if a dog's temperature, which was, at a minimum, measured at the beginning and end of a search, exceeded 106^{O} F. In addition to terminating the search, the dog was not worked for the remainder of the day. During the summer months, dog temperatures were taken at least every thirty minutes. Additionally, dogs were allowed to drink water frequently during searches.

Components of the deployment protocol are detailed in Appendix B. Ideally, the protocol would have been implemented with each dog each day. Such a schedule,

however, was not possible. One reason was the nature of the deployment protocol, which focused on working each dog as long as it was willing and able. Because each dog typically worked on a series of relatively long searches, a single dog often tied up the staff and equipment for most of the available time each day. Therefore, each dog was worked one to two times per week. Dogs were often exercised (i.e., taken from run, walked on lead, or allowed to run around in fenced area) on days that they were not worked.

Individual handlers were not assigned to specific dogs due to the nature of the study. First, allocation of staff work time made individual dog-handler assignments not logistically feasible. Furthermore, because dogs had to be worked for extended periods, it was necessary that they be accustomed to working with different handlers so that handler fatigue did not confound effective search duration (i.e., when a handler became fatigued, another handler could take over working the dog).

It might be tempting to presume that no more training occurred subsequent to the pre-training phase and that all behavioral contingencies were held constant during the testing phase. However, it is important to appreciate that the behavioral contingencies specified in the deployment protocol involved a continuous training process, as is the case with normal operational activities for any detector dog. Although the deployment protocol was fundamentally the same as the final stages of the pretraining protocol, over the 12-month period continual adjustments were made to different aspects of the protocol for each dog. Most such adjustments involved relatively subtle changes necessary to maintain a good detection repertoire (e.g., changes in the frequency of contact with targets and modifications in the treatment of incorrect responses).

As the project staff gained experience with the challenge of working dogs for relatively long periods, some changes were implemented for all the dogs as a group that were necessary to optimize their performance in various ways. Such changes were not necessarily minor. For example, the criteria for the number and spacing of training aids were changed more than once in order to generate improved detection accuracy over longer periods. These experiences provided evidence of the influence of such factors on detection performance and will be discussed further below. Details concerning such changes are included in Appendix D.

In the testing phase, all correct alerts were reinforced by presentation of a rubber kong toy. The dog was allowed to retrieve two or three throws of the kong off lead or allowed to chew on it for approximately 1 minute. Initially, misses resulted in re-searching a limited area until the dog alerted. This practice was terminated because this correction could be made only after a search of the entire site (otherwise there was still an opportunity for the dog to detect the target) and it altered the handler's behavior (change in search pace, increase in frequency of prompting) to such a degree as to offer limited benefits. Therefore, misses were simply scored as such and searching continued according to protocol. However, false alerts were followed by re-searching the immediate area until an alert was not given.

An alert response was considered a hit if the dog sat within 6 m of the target or within 6m of an area located directly below a target hidden more than 2 m above ground level. Of course, these distances were approximate (not actually measured on most occasions) and subject to the judgement of scorers. Prior to engaging in a final sit response, dogs tended to engage in behaviors typical of those engaged upon initial detection of an odor (change in pace, change in direction, change in sniffing behavior) and sat as near as possible to the target. Likewise, an alert response was considered a *false alert if the response was not within the parameters described above.

A dog was considered to have missed a target if the it passed within approximately 2 m of the target and did not give an alert response. Passes by the target on which the dog did not come within this distance were considered handler misses and scored as such. All of the data in the following results section are inclusive of only dog misses. Handler misses were used primarily as a measure of handler search thoroughness.

Handlers were trained to first search the perimeter of a site in a clockwise direction beginning at the point of entry (Hawkinson, 1998). Following the perimeter search, the remainder of the site and its contents was searched. This portion of the search was also conducted in a clockwise direction. If the site required the search of discrete sections, each section was searched in a clockwise fashion, and the sections were also searched in sequence according to which was approached first when moving in a clockwise direction. Open field searches were approached by following paths perpendicular to the prevailing winds spaced at approximately 3m (5-7 handler paces) intervals beginning as far downwind as feasible. All searching was conducted on lead (1.82m) unless, in the handler's judgement, the dog had detected the target and was having difficulty tracking the odor to its source while on lead. In a few instances, open field searches were conducted using a 9m retractable lead.

4.8 Criteria for Search Termination

Only three variables were used as criteria for ending a search. It has already been noted that physiological measures were recorded from each dog before and after each search. Given that one of the objectives of the study was to work dogs under what might sometimes be physically stressful conditions, these measures were required in order to insure that the search protocol did not result in exceeding safe parameters of canine health (Animal Welfare, 1994). If, at any point during a search, a dog's body temperature exceeded the allowable limits set by the animal welfare protocol (106? F), the search was stopped, and immediate measures were taken to cool the dog. Similarly, if a dog's heart rate exceeded the allowable limits set by the animal welfare protocol (230 bpm), the search was stopped, and immediate measures were taken to cool/calm the dog. Lastly, a search was stopped if, at any point during a search, a dog showed a sharp decrease in search rate or search activity. In the interest of objectively defining this variable, each dog wore a pedometer attached to its harness. The plan was to use this overall measure of activity to provide staff with a clear basis for making consistent judgments about when to end search sessions. Staff took pedometer readings every 10 minutes during searches. Pilot data suggested that a sharp drop (75%) in one reading compared to the previous reading would indicate that the dog was no longer working as

actively as before and would therefore give staff a clear rule for when to terminate a search. The objective was to avoid staff making judgments based on factors other than the dog's search activities and to make such calls in a consistent manner.

4.9 Measurement

In order to maximize the benefits of the considerable investment of resources in this project, an extensive array of variables were routinely examined. A number of measures were acquired in order to document different aspects of each dog's performance. Physiological measurements were made in order to examine how the physiology of the dogs was affected by search conditions and to safeguard their health. Another set of factors was recorded to document the conditions under which searches were conducted. Still other factors were recorded to aid in maintaining compliance with the deployment search protocol, which involved a number of different staff over the course of the project. Appendix A details the variables that were routinely measured.

Data were collected by one of the two members of the team assigned to each day's search schedule. Data were recorded manually and later entered into a computer database. To ensure accuracy of the database, 100% of the data were checked for correct entry two times by two additional staff members. Altering the computer database required the concurrence of two staff members.

5.0 Findings

5.1 Performance Characteristics

This section describes a variety of performance measures for the dogs. Figure 1 shows percent hits (i.e., correct alerts) for searches of different duration. Search duration is grouped into 30-minute intervals. Searches ranging from 6 minutes (the shortest search) to 30 minutes serve as the baseline performance, as the duty cycle standard in the canine detection community is 30 minutes. A slight decrease in performance (percent hits) is seen during searches of 31-60 minute duration, and a gradual increase in performance is seen as search duration exceeds 60 minutes; however, there were considerably fewer searches within the longer duration intervals. The decreases in performance from baseline during the 31-60 and 61-90 minute intervals are due to the performance of one dog in particular, the Belgian Malinois, Marco.

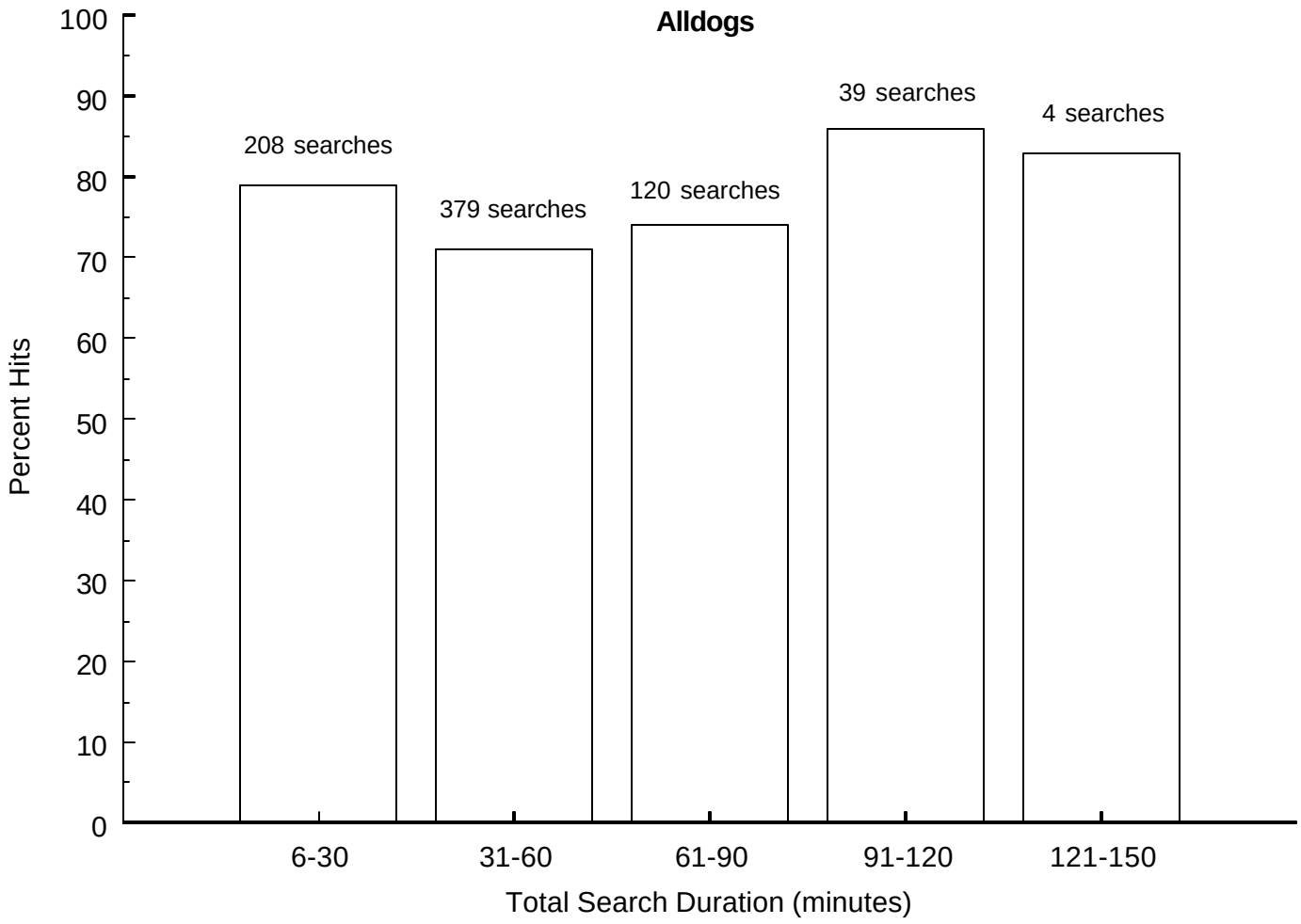


Figure 1. Percent hits for searches of different duration across dogs.

When graphed without Marco (Figure 2), the data show fairly stable performance through the first three time intervals, with percent hits increasing in the last two intervals; however, there were considerably fewer searches within the longer duration intervals. This suggests that as compared to the arbitrary, but often noted, baseline of 30 minute search duration, dogs are capable of extended searches. The absence of a decreasing trend in percent hits also indicates that the training and handling practices employed in this study were appropriate for examining duty cycle parameters.

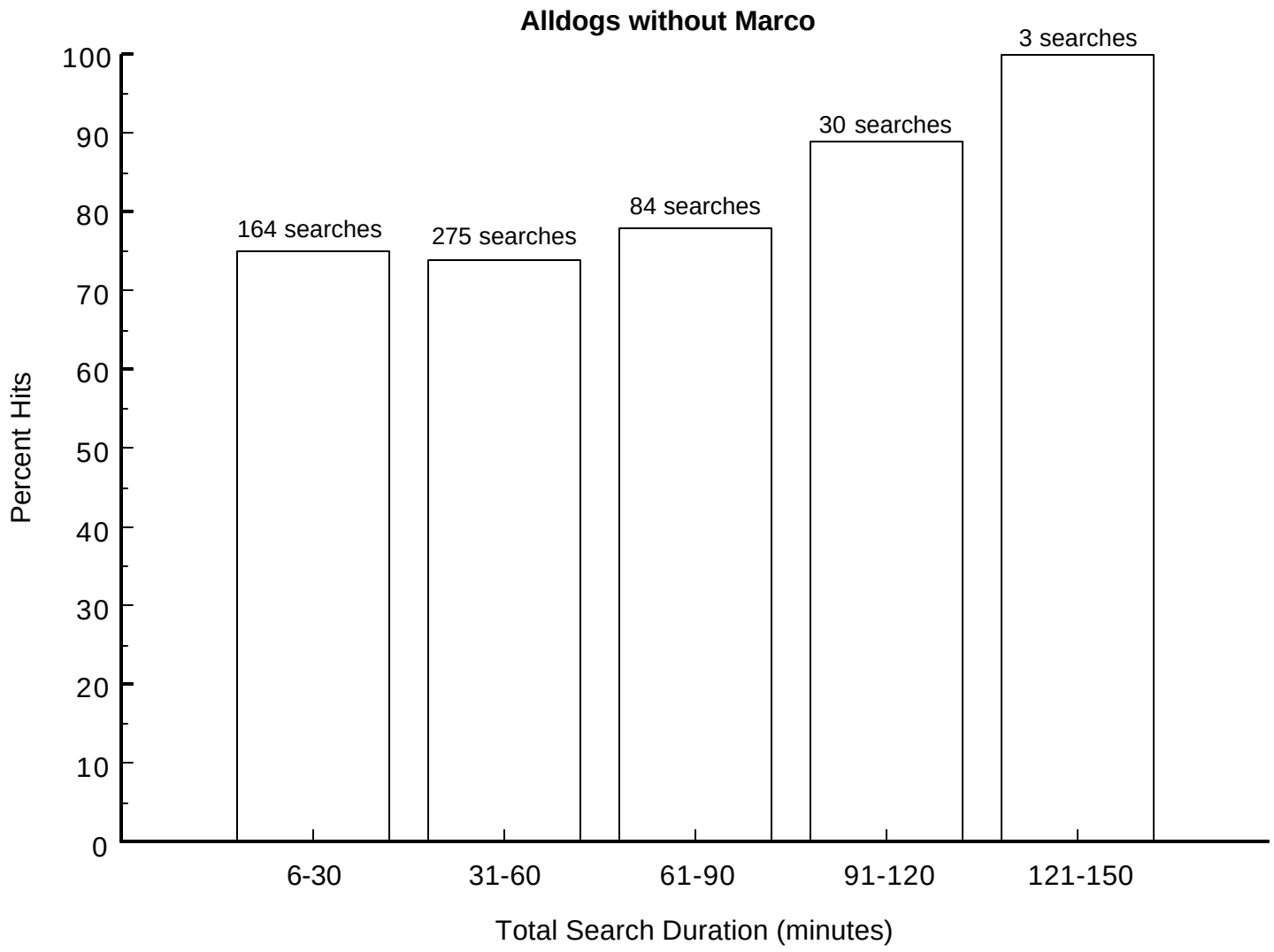


Figure 2. Percent hits for searches of different duration for all dogs without Marco.

Figure 3 shows the ratio of false alarms to number of searches for searches of different duration. The number of searches and false alarms (false alarms/searches) contributing to the resultant ratio are displayed above the bar depicting the ratio at each interval. Again, search duration was grouped into 30-minute intervals. Searches ranging from 6 minutes to 30 minutes serve as the baseline performance, as the duty cycle standard within the canine detection community is 30 minutes. Data show that as search duration increased, the ratio of false alarms increased. As the opportunity to emit a false alarm increases as search time increases, this trend is expected.

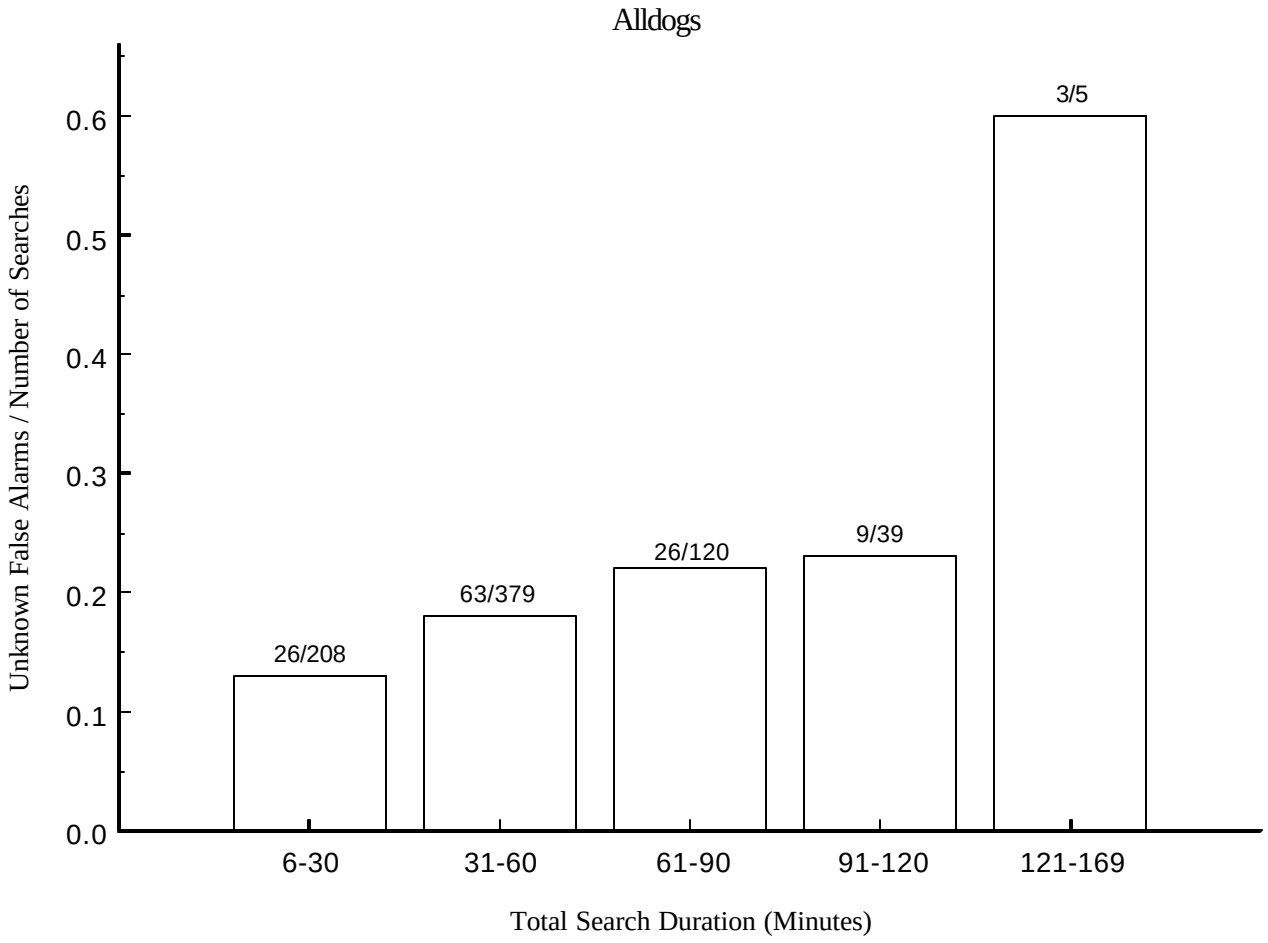


Figure 3. False alarms for searches of different duration across dogs.

Figure 4 shows the relationship between percent hits and serial order of searches within a workday for all dogs. These data were sorted in such that performance measures for the first searches of all days across all dogs were combined and averaged, the second searches of all days across all dogs were combined and averaged, and so on. Performance was consistent across search order, suggesting that no deterioration in performance necessarily results from repeated searches. This result also suggests that the training and testing protocols created an appropriate context in which to assess duty cycle parameters.

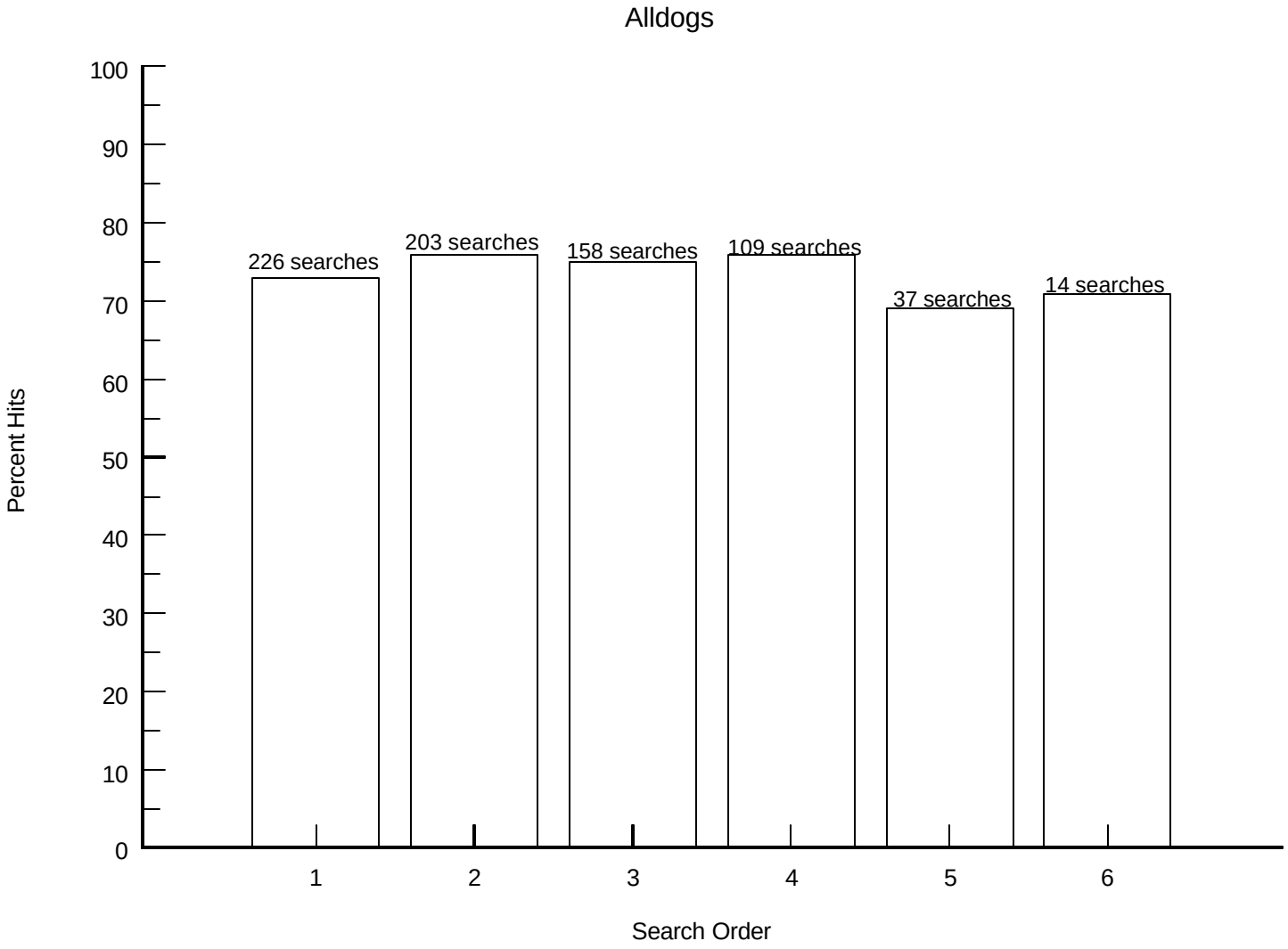


Figure 4. Percent hits for order of a search within a workday.

Figure 5 shows the relationship between false alarms and search order. The number of searches and false alarms (false alarms/searches) contributing to the resultant ratio are displayed above the bar depicting the ratio at each interval. False alarm ratio was relatively consistent across search order, indicating little effect of search order and again suggesting that the procedures were appropriate for examining the duty cycle.

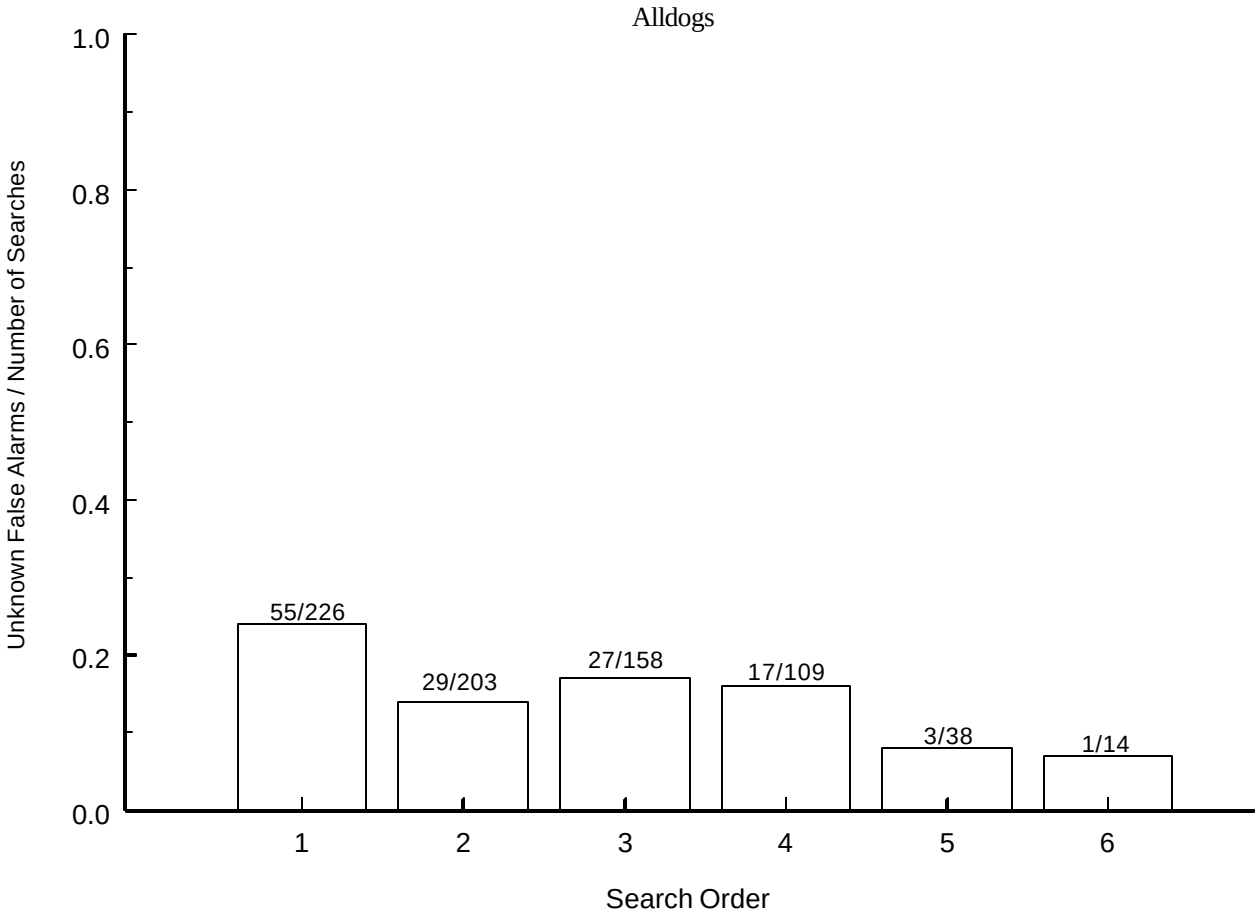


Figure 5. False alarms for order of a search within a workday.

Figure 6 shows the relationship between percent hits and elapsed search time. In this graph, performance (percent hits) is examined in relation to the first, second, third, and fourth 30-minute increments of any search. Data show that performance did not increase or decrease with elapsed search time, but instead remained fairly stable.

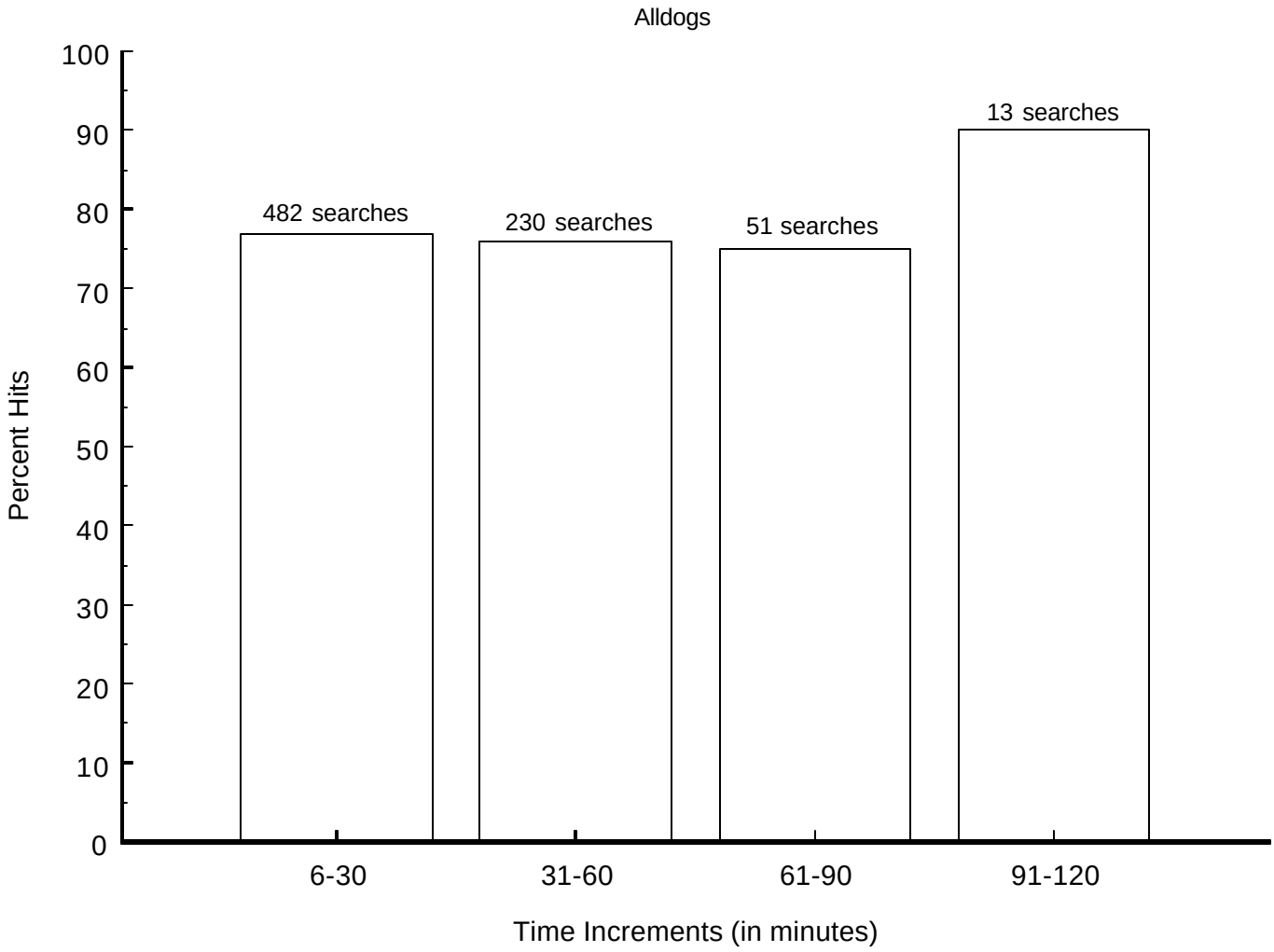


Figure 6. Percent hits as a function of elapsed search time.

Figure 7 shows the relationship between false alarms and elapsed search time. The number of searches and false alarms (false alarms/searches) contributing to the resultant ratio are displayed above the bar depicting the ratio at each interval. In this graph, the ratio of false alarms is examined in relation to the first, second, third, fourth, fifth, and sixth 30-minute increments of any search. Data show that the ratio of false alarms decreased as elapsed search time increased to 90 minutes. After 90 minutes of elapsed search time, false alarms appear to increase; however, this trend may be an artifact of the relatively few number of searches lasting longer than 90 minutes.

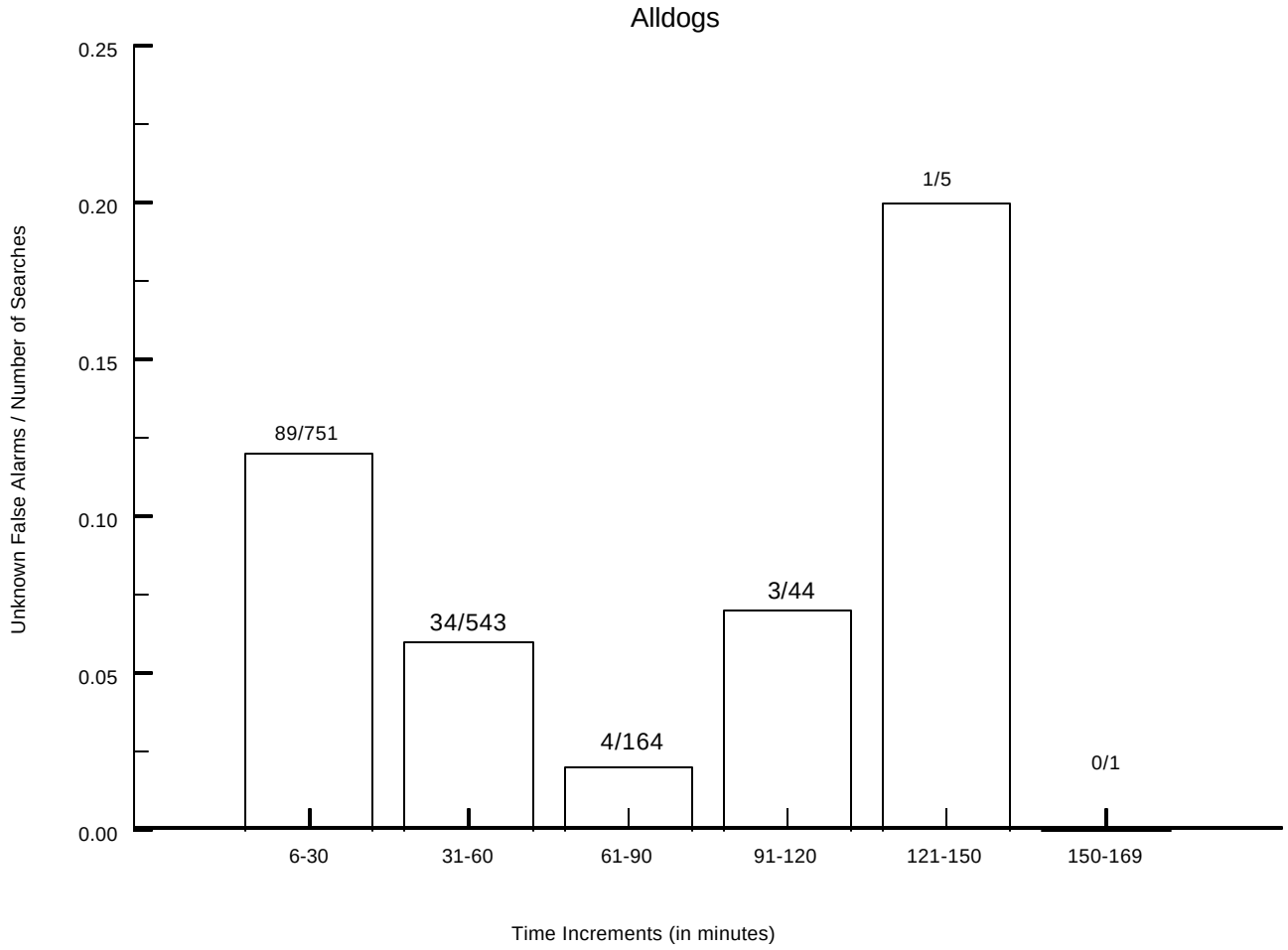


Figure 7. False alarms as a function of elapsed search time.

Figure 8 shows the average detection performance (percent hits) for all dogs following different intervals of downtime, which is the amount of time between searches. The black circles represent weighted averages, which reduce the influence of discrepant numbers of observations from each dog contributing to the average. Gray triangles represent non-weighted averages, which were the only available metric for longer downtime intervals, since weighted averages cannot be appropriately applied to the low number of observations within these longer intervals. Keeping in mind that single observations have a significant impact on the averages at longer intervals, these data may be interpreted as indicating little performance difference in relation to varying downtime between searches.

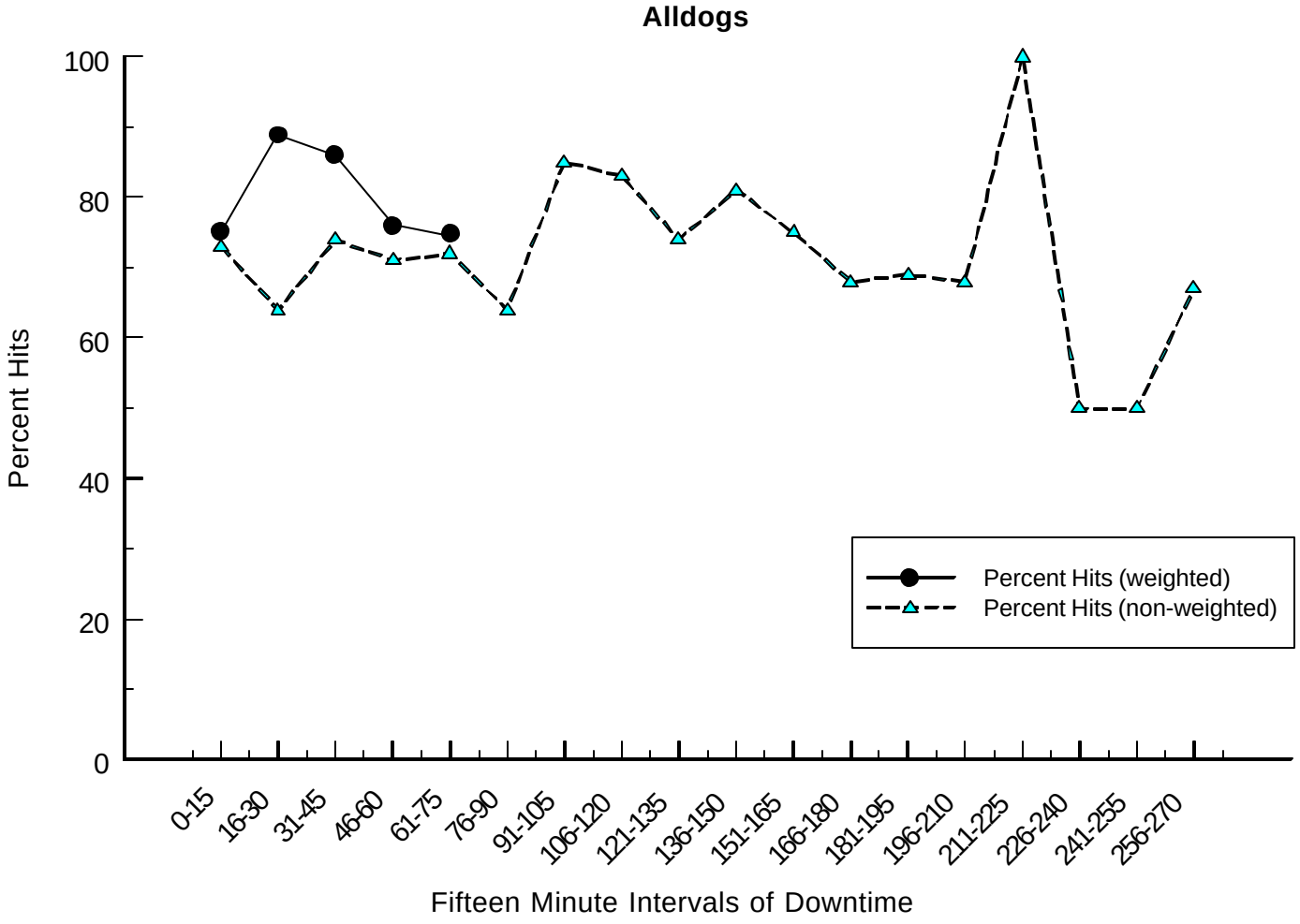


Figure 8. Percent hits across dogs following different intervals of downtime.

Figure 9 shows the average false alarms for all dogs following different intervals of downtime. As in the previous graph, black circles represent weighted averages and gray triangles represent non-weighted averages. An increased number of false alarms per number of searches is evident as downtime increased, however, once again, there were fairly limited observations at longer down time intervals.

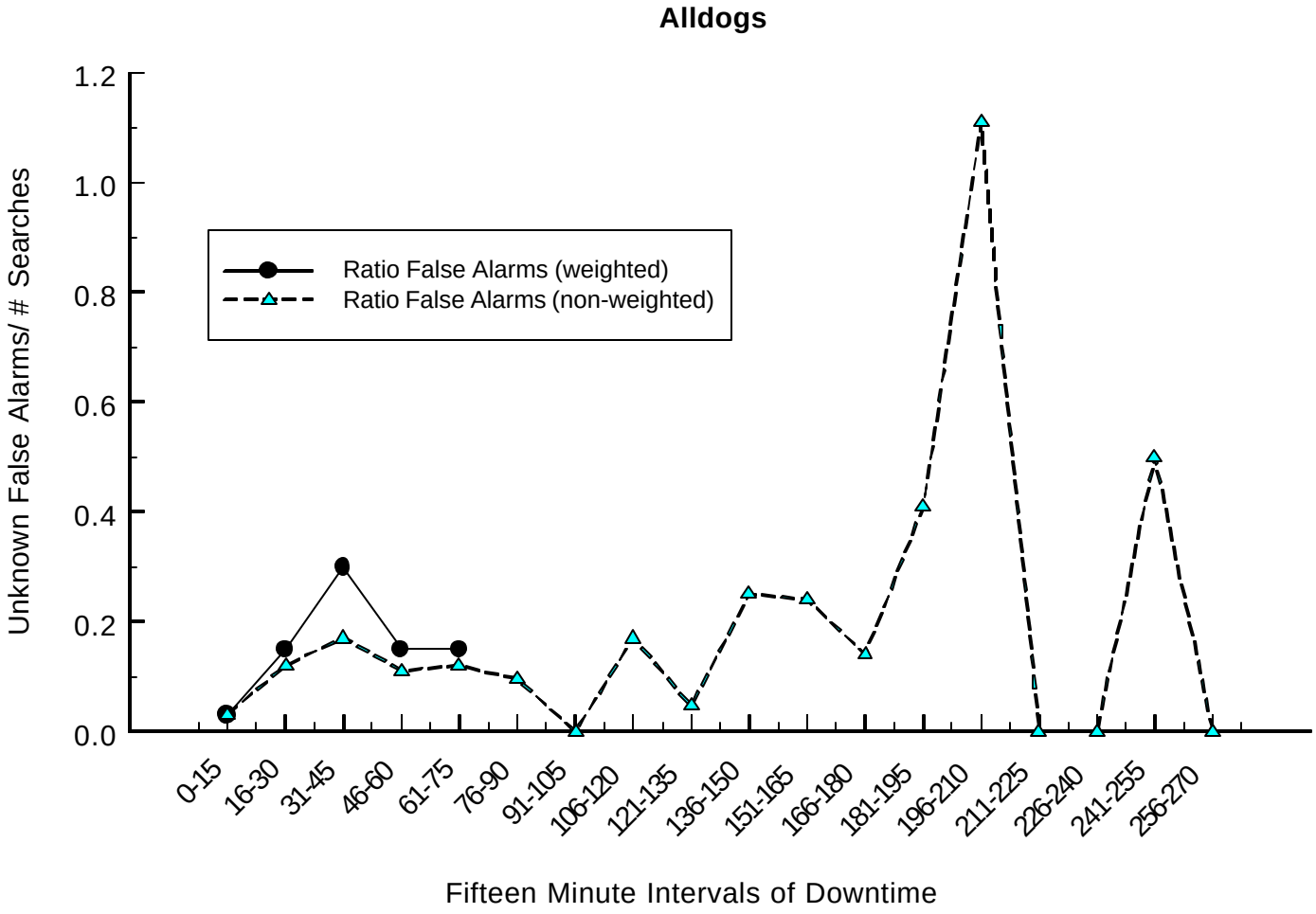


Figure 9. False alarms for all dogs following different intervals of downtime.

5.2 Search Terminations

Each site was searched in its entirety unless impeded by specific human and/or canine factors. Human factors included the end of the workday or other similar unavoidable circumstances. Canine factors included exceeding a physiological limit or exhibiting decrements in search rate or willingness to search. Only 107 searches out of 751 total searches were terminated for these factors. Sixty-eight of the 107 were stopped for human reasons. Forty-one searches were terminated due to canine factors. All 41 searches were terminated because a dog's body temperature exceeded its physiological limit (106? F). No dog exceeded the physiological limit for heart rate (230 bpm). Dogs did not exhibit significant decreases in search rate, nor was any dog ever unwilling to work. During the course of the study, no dog ever exhibited obvious signs of physical distress related to working (e.g., lethargy, lack of coordination, vomiting, diarrhea, etc).

5.3 Duty Cycle

The data presented in the preceding section are important partly because they represent the observations of an unusual opportunity to measure the performance of detector dogs under consistent but otherwise realistic operational search conditions. However, their primary function is to provide a clear picture of how long detector dogs are able and willing to work effectively. As already noted, the study therefore created training and search protocols that would result in dogs working as long as possible, given unavoidable logistical limitations.

Table 1 shows some data that will aid in describing the duty cycle findings. It has already been noted that it was not logistically possible to work each dog as often as desired during the 12-month period of the study. It is therefore not possible to know whether the dogs might have been less willing to work had they worked more days per week.

Table 1. Summary measures of duty cycle parameters for each dog and all dogs.

Measure	Booga	Marco	Sadi	Sam	All Dogs
Total days worked	54.0	54.0	61.0	61.0	230.0
Total # searches	161.0	177.0	219.0	194.0	751.0
Mean search duration in minutes	41.9	46.3	45.6	49.5	47.4
Mean duration of search time per day in minutes	124.9	151.9	163.8	157.3	150.2
Mean duration of work day in minutes	301.6	398.5	418.6	389.5	377.0

Table 1 includes mean search duration, mean search time per day, and mean total time of the working day (i.e., generally out of the kennel).

Within the context of the study, the maximum effective duty cycle under moderate environmental conditions was *at least* 91-120 minutes of continuous searching. Data show that elapsed search time and total search duration were weakly related to number of false alarms, trends are expected, given that as search time increases, the opportunity to emit false alarms increases. Data also show that elapsed search time, total search duration, and search order were not related to probability of detection.

In summary, the data show that all four dogs were willing and able to work as long as asked: In other words, the dogs did not provide their own limits. The conditions of the study did not exceed their capabilities to work for extended periods.

5.4 Performance Correlates

Along with performance measures, an extensive array of physiological and environmental variables was recorded under all the operational conditions. These variables were measured in order to examine how canine physiology is affected by search conditions and to safeguard the health of the dogs. Environmental factors were recorded in order to document conditions under which searches were conducted and their relation, if any, to performance.

This section relates performance characteristics to physiological and environmental variables. These relationships aid in evaluating the possibility that some of these variables influence detection performance. The wealth of data routinely collected as part of the measurement protocol allows calculation of numerous correlations, which may be found in Appendix E. Many of these relationships are obvious and do not warrant attention (e.g., body temperature and heart rate or body temperature and environmental temperature). Other relationships are not practically meaningful and will be ignored (e.g., number of errors made in one search and total daily search duration). Instead, discussion will focus on those relationships that might generally be assumed to be important.

For example, consider the relationship between ending body temperature and performance measures. Figure 10 plots percent hits as a function of the dog's body temperature at the end of each search for each dog and averaged across dogs. The graphs show the value for each session and a linear line of best fit. A linear line of best fit indicates trends, i.e., increases or decreases, in data. Although informative, trends are not always indicators of significant relationships between measures. Two dogs (Booga and Marco) showed a tendency to perform worse with increasing body temperature, and one dog (Sadi) showed no clear relationship. However, only the data for Sam show a statistically significant correlation ($p = 0.01$), and it was a positive (as temperature increased, % hits increased) relationship. It may be concluded that a consistent and meaningful relation between ending body temperature and performance measures can not be generalized to any dog.

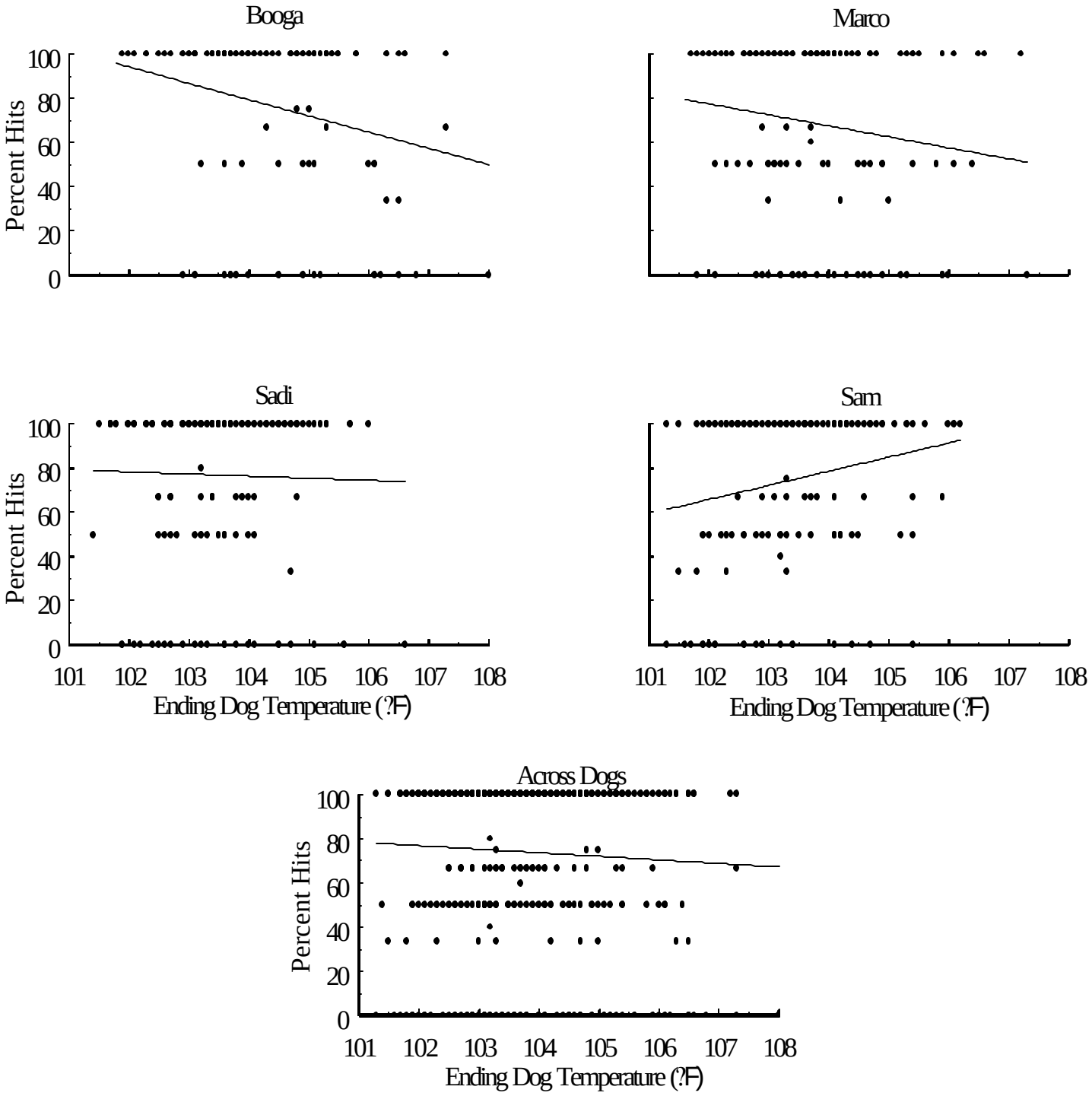


Figure 10. Percent hits as a function of ending dog temperature for each dog and across dogs.

Figure 11 shows the relationship between ending body temperature and another performance measure - number of false alarms. It is easy to see from these graphs that this performance measure does not vary systematically with this variable for any dog.

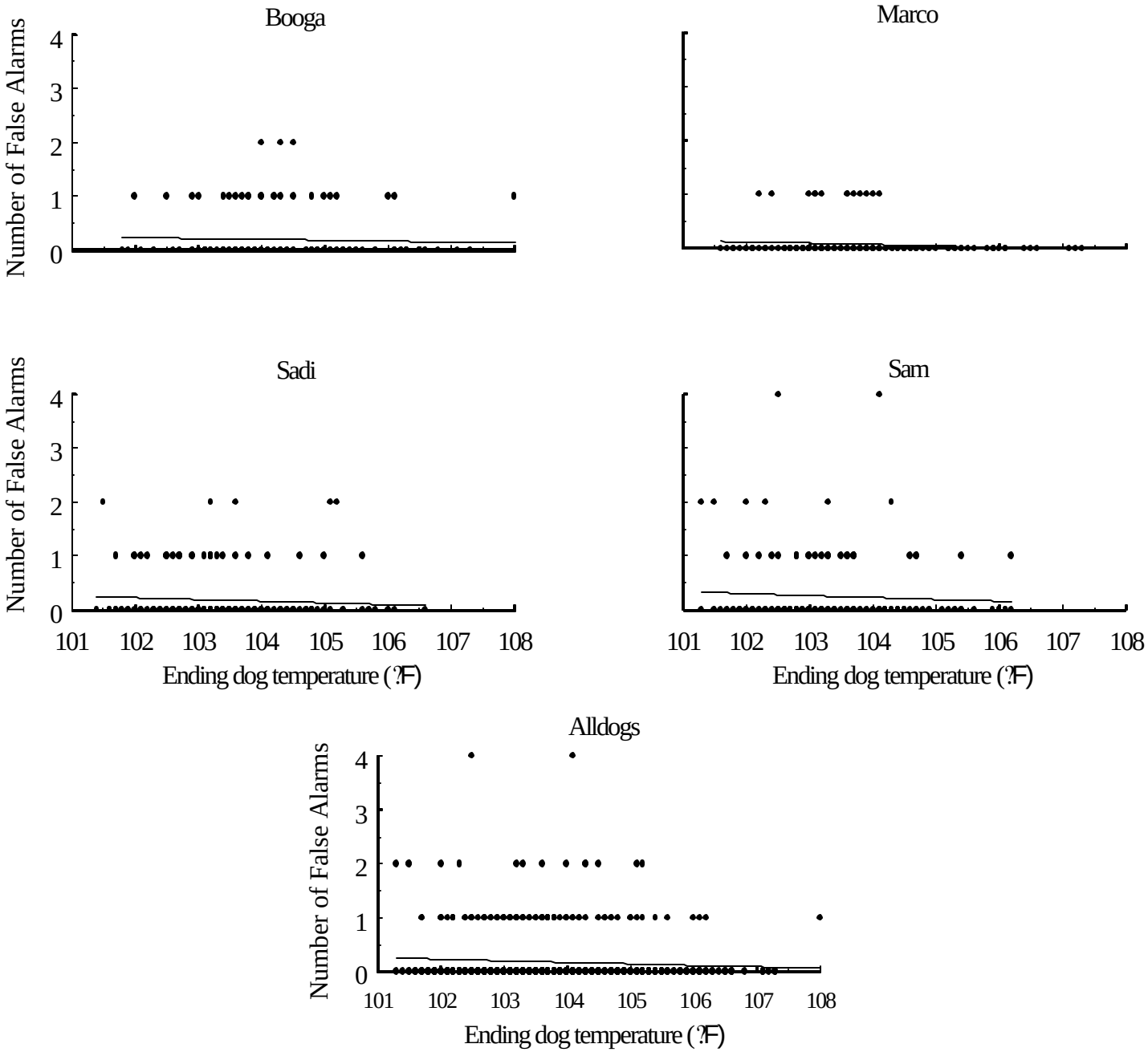


Figure 11. Number of false alarms as a function of ending dog temperature for each dog and across all dogs.

The following figures address relationships between environmental variables and basic performance measures. Figure 12 shows the relationship between ending environmental temperature and percent hits. All functions show some degree of negative (as ending temperature increase, % hits decreases) correlation, but only those for Booga, Marco, and all dogs are statistically significant.

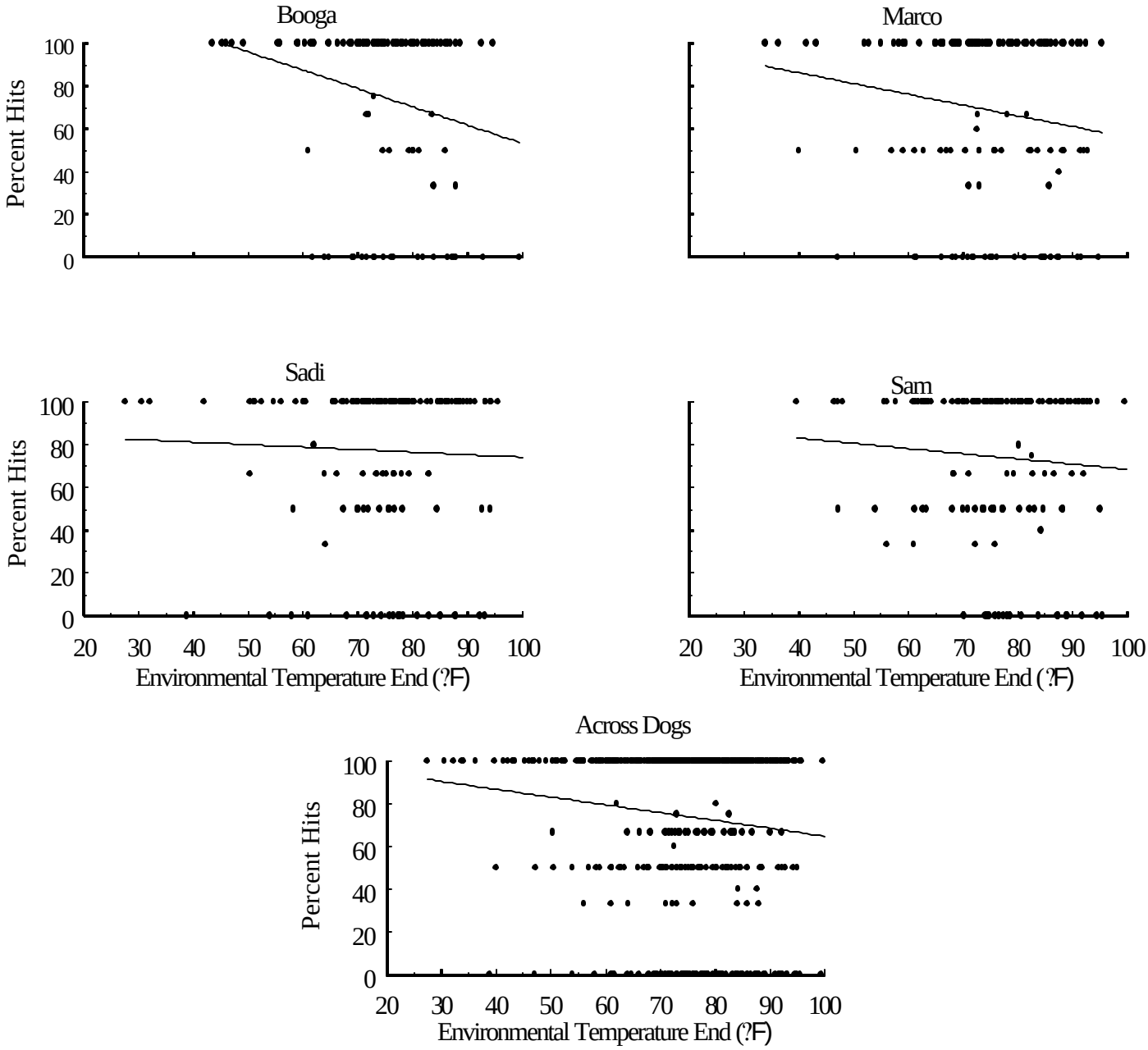


Figure 12. Percent hits as a function of ending environmental temperature for each dog and across all dogs.

Figure 13 shows the relationship between ending environmental temperature and number of false alarms. None of the correlations are statistically significant.

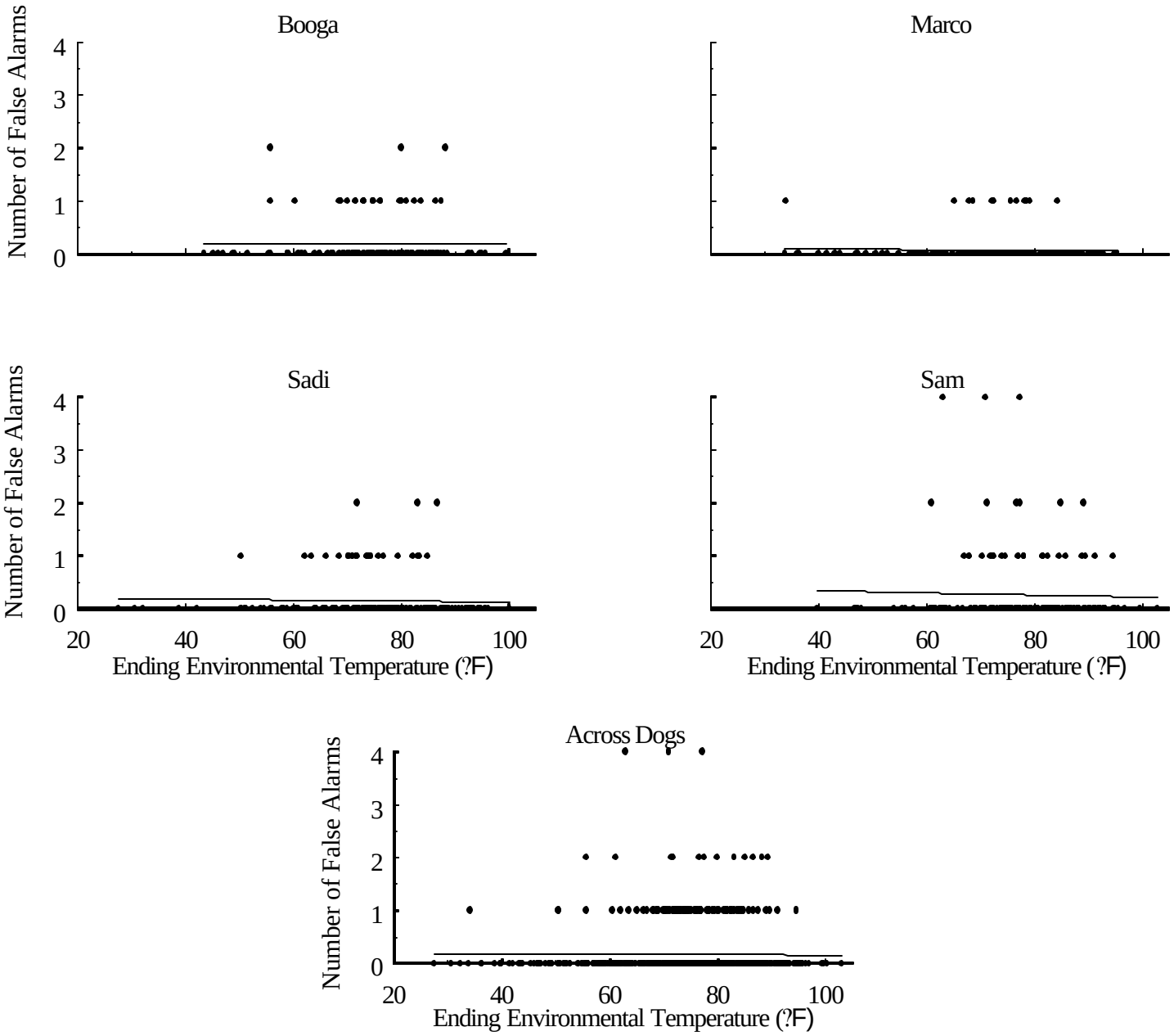


Figure 13. Number of false alarms as a function of ending environmental temperature for each dog and across dogs.

Dog handlers and canine program managers consistently report that high heat (>85 F) coupled with high humidity (>70%) reduces effective canine working time. Although no decrement in performance was observed under combined high heat and humidity, these parameters were necessarily constrained by the conditions encountered in Auburn. Only 17 searches were conducted in which both temperature was greater than 85? F and percent humidity was greater than 50%. Dogs are, of course, deployed in areas where more extreme conditions are routine (e.g., southern Florida). This study could not address more extreme conditions than were available, thus, the best information available is that extreme heat + high humidity decreases dog performance. However, it warrants consideration that the dogs in this study were specifically trained and conditioned to perform extended searches in the prevailing conditions.

6.0 Discussion

6.1 Duty Cycle Findings

Perhaps the most important finding about the duty cycle is that none of the dogs refused to work when prompted, had significant reductions in search rate, or exhibited declining detection performances over time. Although they might have slowed down somewhat under some conditions, they continued to search when commanded and continued to find targets. This finding is particularly encouraging because it suggests that the dogs did not bring their own limits to the task. Although it is reasonable to assume that some limits exist under which dogs would quit or perform poorly, the accumulated experience during this project suggest that trainers and handlers can have a substantial impact on how long their dogs are willing and able to work effectively.

Within practical limits, dogs will work for extended periods of time if they are trained to do so. Within the context of this study, search sites and logistical support accommodated long search scenarios, both key aspects in training for extended searches. Another critical aspect in training the dogs in the study to work for extended periods involved target probability. This required dispersing training aids throughout the search pattern such that the dogs searched for extended periods of time before encountering the hides (33 min per target on average), but also encountered a sufficient number of hides so that there would be enough reinforcement opportunities to maintain search behavior over the required periods of time.

6.2 Contributing Variables

An important aspect of this study was its consideration of a number of variables that could influence duty cycle outcomes. Environmental and physiological variables were measured in order to assess their impact, if any, on the performance of the dogs. Conditions existing in Auburn, Alabama at the time of the study may not have been extreme enough or representative of operational conditions experienced by other canine programs. The duty cycle is specific to the operational mission; the particular operational missions of other detection dog programs may require that dogs work in even more arduous conditions than those experienced by the dogs in this study.

The body temperature of the dogs at the end of each search, when their temperature is presumably highest, showed a statistically significant correlation for one dog for one performance measure - percent hits. There was only one statistically significant correlation between ending heart rate and any performance measure.

There is slightly more evidence that the temperature of the search environment is correlated with poorer performance. Two of the four dogs showed a statistically significant negative relationship between environmental temperature and percent hits (as well as the all dogs aggregate), but none of the correlations with false alarms or errors were statistically significant. None of the correlations between relative humidity and these performance measures were statistically significant. Again, this study could not examine performance under more extreme conditions, which may produce more deleterious effects on dog performance, than those afforded by the prevailing climate of Auburn, Alabama. The temperatures experienced in this study ranged from 18.3?F to 102.9?F with a combined mean of 74.6?F. Extremely low temperatures, below freezing, may also impact detection by virtue of reducing the vapor emitted from target material. However, conditions in Auburn were never representative of sustained low temperatures.

In sum, although correlations between the body temperatures of dogs and the environmental temperatures taken at the end of searches were statistically significant (see Appendix E), these variables were not strongly and consistently related to performance measures. The effects of environmental temperature and humidity on handlers may be a source of comment or complaint, but these data suggest that it may not be useful to assume that dogs have the same reactions. After all, human physiology is different from canine physiology and human reactions to environmental conditions are greatly influenced by how social experiences have taught us to react. Dogs do not suffer such constraints unless functionally trained to by their handlers. These findings certainly do not mean that adverse environmental conditions do not affect the performance of detector dogs, but the effects may be less strong and less general than is suspected. Furthermore, it may be that the better trained and conditioned a dog is, the less it is influenced by factors that are extraneous to its task.

7.0 Summary of Findings

The study has shown that:

1. Within the context of the study, the effective duty cycle under moderate environmental conditions was at least 91-120 minutes of continuous searching. Data show that all four dogs were willing and able to work as long as asked: In other words, the dogs did not provide their own limits. The conditions of the study did not exceed their capabilities to work for extended periods.

2. Environmental and physiological variables were not strongly related to duty cycle measures. Only one dog showed a statistically significant positive

relationship between percent hits and body temperature. Two of the four dogs showed a statistically significant negative relationship between percent hits and environmental temperature. No correlations between performance and relatively humidity were statistically significant. However, this study could not address more extreme conditions, which may effect dog performance, than that afforded by the prevailing climate of Auburn, Alabama.

3. The study suggested that training detector dogs to work for long periods requires that certain features of training and deployment protocols be treated in a particular manner. These features include the size of search settings, the number of hides used, and the distribution of hides.

8.0 Acknowledgments

This project involved substantial contributions by a number of individuals. The following persons trained and handled the dogs under often challenging weather conditions and warrant special recognition: Leslie Busbee, Patricia Cornwell, Jennifer Edmonds, Kevin Mullins, and Karen Rader. These individuals were also responsible for data entry and participated fully in data analysis activities following the conclusion of the project. In addition, we appreciate the assistance of the staff of the IBDS Chemistry laboratory in preparing training aids. Hillary Hunt, Meredith Jones, Debbie Kerr, and John Porter also deserve special recognition for their help with both training aid placement and data collection. Ed Hawkinson deserves special recognition for lending his knowledge, experience, and assistance to the project, as does Dr. Paul Waggoner for his assistance in editing the report. Additionally, this project would not have been possible without the cooperation of numerous individuals and businesses allowing us access to their facilities. Finally, we are indebted to Dr. Susan Hallowell of the FAA Tech Center for suggesting the concept of this project and supporting the effort (FAA Grant # 97-G-020).

9.0 References

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Duty Cycle (1996). *In Defense Information Systems Agency* [Online]. Available: http://www-library.itsi.disa.mil/org/fed_std/html/dir-013/_1849.htm [2000, April 13].

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Erratum

To Accompany

"Duty Cycle of the Detector Dog: A Baseline Study"

Page 10, Figure 1

Caption above bar graph displaying percent hits as a function of search time should read "172 searches", "322 searches", "103 searches", "33 searches", and "4 searches" respectively from left most bar to right most bar. These are the total numbers of searches minus the number of searches in which there were no targets hides present.

Page 13, Figure 4

Caption above bar graph displaying percent hits as a function of search order should read "181" searches", "176 searches", "128 searches", "99 searches", "32 searches" and "9 searches" respectively from left most bar to right most bar. These are the total numbers of searches minus the number of searches in which there were no targets hides present.

Page 15, Figure 6

It should be noted that for graphs displaying percent hits (Figure 1, page 10; Figure 4, page 13; Figure 6, page 15; Figure 8, page 17; Figure 10, page 21; Figure 12, page 23), searches with no target hides are not included.

Pages 17 & 18, Figures 8 and 9

The values indicated as "weighted averages" were arrived at in the following manner:

First, the number of observations for each dog across time bins was normalized by only using a number of observations equal to the smallest number of observations in any single time bin. For example, if there were only 2 time bins and bin 1 = 10 observations and bin 2 = 8 observations, only 8 observations from bin 1 was selected for use in further "weighted" calculations. Next the following calculation was employed to determine weighted group means per time bin:

$$\frac{\text{(total normalized observations all dogs)(total normalized hits all dogs)}}{\text{total normalized observations all dogs}}$$

This manipulation was made so that individual observations across dogs have equal influence on the group mean. For downtime greater than 75 minutes, there were very few (e.g., 0,1,2) for most dogs in most bins, therefore, these group means were not normalized or weighted. As the text cautions, there are few observation at longer downtimes and these data points should be given little interpretive value.

Page D-1, Appendix D

The reference "closed Sadi's economy" refers to actions taken to, as much as possible, limit social reinforcement (e.g., praise, petting, & play) outside of the "working" context. This was done in response to a reduction in her detection performance with the hope that it would increase the efficacy of social reinforcement in the "working" context, in the same way that deprivation of food increases the efficacy of food as reinforcement of desired responses. No effects on performance could be attributed to this manipulation.

Page E-1, Appendix E

The following explanations of the statistical terms and procedures are provided to aid in the interpretation of results presented in Appendix E (excerpts from Zar, J.H. (1996) Biostatistical Analysis, 3rd ed):

A correlation is a measure of the direction and degree of relationship that exists between two variables. The degree of relationship can vary anywhere form being nonexistent to being perfect. Relationship is expressed as a linear function (relationship). A correlation coefficient (*r)* expresses quantitatively the magnitude and direction of the correlation. The correlation coefficient can vary from +1 to –1. The sign of the coefficient tells us whether the relationship is positive or negative. The numerical part of the correlation coefficient describes the magnitude of the correlation. The higher the number, the greater the correlation. Since 1 is the highest number possible, it represents a perfect correlation. A correlation coefficient of +1 means that the correlation is perfect and the relationship is positive. A correlation coefficient of -1 means that the correlation is perfect and the relationship is negative. When the relationship is nonexistent, the correlation coefficient equals 0. Imperfect relationships have correlation coefficients varying in magnitude between 0 and 1. They will be plus or minus depending on the direction of the relationship. The correlation coefficient is calculated as:

$$r = \frac{?xy}{\text{sq root } (?x^2\ ?y^2)}$$

R^2 is called the coefficient of determination; r^2 equals the proportion of the total variability of *Y* which is accounted for or explained by (attributed to) *X*. It may be described as the amount of variability in one of the variables (either X or Y) accounted for by correlating that variable with the second variable. It is calculated as by squaring the correlation coefficient (r^2). As in regression analysis, r^2 may be considered to be a measure of the strength of the linear or straight-line relationship.

Adjusted r^2, (r_a^2), is referred to as the adjusted coefficient of determination, and is more acceptable measure of the "goodness of fit" of the regression line. Whereas r^2 always

increases when a value is added to a variable (or observation) within a regression model, r_a^2 will increase only if an added variable results in an improved fit of the regression equation to the data. If r_a^2 is a better estimate of r^2, and if r^2 is near zero, the calculated r_a^2 may actually be negative. This value is calculated as:

$$r_a^2 = 1 - \frac{n-1}{n-m-1}(1-r^2)$$

*where n = total number of observations and m = number of independent variables in the regression model.

The alpha level (the probability or *p*-value) is the threshold probability level against which the obtained probability is compared to determine the reasonableness of the null hypothesis. (The null hypothesis states that the independent variable has no effect on the dependent variable *or that no relationship between two variables exists*). It also determines the critical region for the rejection of the null hypothesis. Alpha is usually set a 0.05 or 0.01. The alpha level is set at the beginning of the experiment and limits the probability of make a Type I error. (A Type I error occurs when the null hypothesis is rejected and it is true).

> $p < 0.05$= 95% probability that a relationship exists between the variables; or, 5% probability that chance alone is responsible for differences between variables.
>
> $p < 0.01$= 99% probability that a relationship exists between the variables; or, 1% probability that chance alone is responsible for differences between variables.

Sometimes it is desirable to know the value of a population mean. Since it is very uneconomical to measure everyone in the population, a random sample is taken, and the sample mean is used as an estimate of the population mean. The next step is to determine how close the sample mean is to the population mean. The usual way to answer this question is to calculate a range of values for which one is reasonably confident that the range includes the population mean. The wider the range, the greater the confidence that the range contains the population mean. These ranges are called confidence intervals. Therefore, a confidence interval is a range of values which probably contains the population mean. It is possible to quantitatively construct confidence intervals about which there are specified degrees of confidence. The 95% confidence interval is an interval such that the probability is 0.95 that the interval contains the population value. Thus, when a 95% confidence interval is specified, what is meant is that the probability is 0.95 that the interval contains the population mean.

APPENDIX A

TABLE OF SUMMARY DESCRIPTIVE DATA

SUMMARY DESCRIPTIVE DATA
ACROSS ENTIRE DURATION OF STUDY

	BOOGA	MARCO	**SADI**	**SAM**	**ALL DOGS**
# Targets	210	244	301	292	1047
# Hits	162	164	233	215	774
# Misses	48	80	68	77	273
# Fa	32	13	37	50	132
# Errors	102	116	129	149	496
% Hits	77	67	77	73	73.9
Min/Target	32.12	50.3	33.19	32.86	32.99
Min/Miss	140.52	102.56	146.91	124.62	126.51
Min/Fa	210.78	631.15	270	191.92	261.64
Min/Error	66.13	70.73	77.44	64.4	69.63
Min To 1st Hit Of Search	17.23	20.64	17.79	20	18.94
Min To 1st Hit Of Day	24.74	21.67	26.35	28.62	25.31
Begin Dog Temp	102.43	101.66	102.2	101.91	102.03
End Dog Temp	104.32	103.76	103.43	103.34	103.7
Begin Hr (10 sec)	18.02	16.59	17.43	16.32	17.15
End Hr (10 sec)	19.81	18.11	19.09	17.62	18.71
Dog Temp Change	1.89	2.09	1.43	1.43	1.67
Hr Change	1.73	1.48	1.75	1.32	1.57
Total Search Duration	6745	8205	9990	9596	34536
Average Search Duration	41.89	46.34	45.62	49.46	47.37
Number Of Searches	161	177	219	194	751
# Of Days Searched	54	54	61	61	230
# Searches W/Temp>106	22	9	4	6	41
Search Time Per Day	124.9	151.94	163.77	157.31	150.16
Environment Temp Begin	73.59	72.01	74.47	76.59	74.48
Environment End	74.33	73.10	74.95	77.15	75.22
Environment Temp Change	.62	1.11	.45	.68	.75
Total Out of Kennel Duration	14,776	18,330	22,605	19.864	75,575
Average Out of Kennel Duration	301.55	398.48	418.61	389.49	377.03
Number of Blank Searches	24	25	39	26	114
Proportion of Blank Searches	.15	.11	.18	.13	.15
Min To 1st ufa of day	21.6	22.2	34. 6	20.4	25.2
Min To 1st ufa of day in target trials	22.6	21.4	40.5	21.2	27.2
Min To 1st ufa of day in blank trials	18.0	27.0	13.3	17.4	17.1

APPENDIX B

PROTOCOL

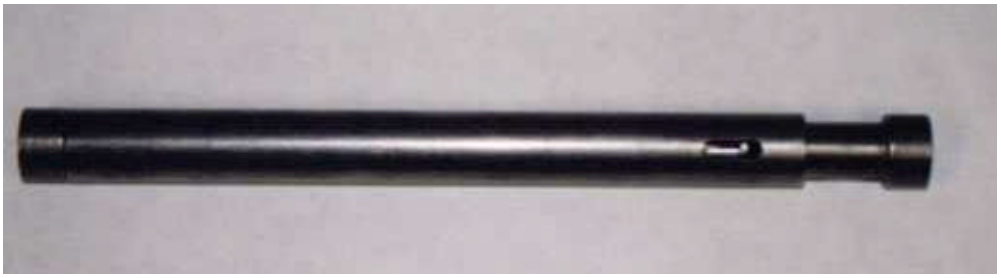
The standard operating procedure for deployment involved the following general components:

1. Travel to the site
2. Water dog
3. Allow dog to eliminate
4. Determination of search parameters and characteristics by the scorer
   4.1. Identifying search area parameters
   4.2. Determining if target(s) would be placed
   4.3. Determining number of targets to place
   4.4. Determining distance of separation for targets
5. Placement of blanks
6. Placement of non-targets
7. Placement of targets
8. Measurement of physiological data by the handler
9. Measurement of environmental data by the scorer
10. Search with handler and dog with scorer recording data
11. Measurement of physiological data by the handler
12. Water dog
13. Allow dog to eliminate
14. Measurement of environmental data by the scorer
15. Retrieval of odor sources

    Travel to the following site if required

APPENDIX C

TARGET DESCRIPTION



Configuration

Stainless steel permeation tube (14cm long x 1.2cm diameter)

Removable cap at one end opens 2.5 cm exposing three 1cm long openings

Odor source materials (1µ-1 ml) placed on cotton inside tube

Target Odors

Geraniol

Dimethyl thiazole

Non Target Odors

L-carvone

Anesole

Tube with cotton only (blanks)

APPENDIX D

LIST OF CHANGES MADE DURING THE COURSE OF THE STUDY

10/26	Started non-targets
11/9	Began recording data
1/15	Rader started handling
1/15	Began running through lunch
1/29	Stopped non-targets
2/1	Changed source volume (geraniol=5?l, DMT=1?l)
2/10	Stopped running through lunch
2/12	Began running on gloves
2/19	Modified reinforcement density
3/4	Busbee stopped handling
3/22	Corrected for too much prompting
4/7	Mullins started handling
4/12	Identified medical problems with Sam
4/14	Began Sam's medication
4/23	Changed source volume (geraniol=1?l, DMT=1?l)
5/7	Stopped placing blanks (decision made 5/7 –fri, implemented on 5/10)
6/21	Resumed running through lunch
6/23	Began feedback sheets
6/23	Resumed placing blanks
6/23	Stopped retraining misses
6/25	Closed Sadi's economy (decision made 6/25 –fri, implemented on 6/28)
7/26	Busbee started handling again
8/18	More verbal ups
8/18	Scorer provides feedback regarding compliance during searches
8/26	Changed target density
	Changed source volume to 1?l both compounds
9/7	Increased source material volumes (geraniol=5?l, DMT=3?l)
9/20	Changed odor source material volumes ((geraniol=3?l, DMT=1?l)
11/9	Ended data collection

APPENDIX E

TABLE OF CORRELATIONS

R-SQUARED, ADJUSTED R-SQUARED, AND PROBABILITY VALUES FOR VARIABLES (P< 0.05 SHADED)
A "P" VALUE OF LESS THAN 0.05 INDICATES A STATISTICAL SIGNIFICANCE

1.0 Percent hits

IV	Booga	Marco	Sadi	Sam	Alldogs
# of targets	0.00 -0.01 0.66	0.01 0.00 0.32	0.00 0.00 0.43	0.01 0.00 0.23	0.00 0.00 0.59
# FA	0.00 0.00 0.43	0.00 -0.01 0.68	0.02 0.00 0.06	0.00 0.00 0.42	0.00 0.00 0.15
Minutes to first hit	0.16 0.15 <0.01	0.16 0.16 <0.01	0.13 0.12 <0.01	0.08 0.08 <0.01	0.12 0.12 <0.01
Minutes to first FA	0.00 -0.05 0.86	0.79 0.76 <0.01	0.08 0.04 0.16	0.03 -0.01 0.37	0.00 -0.01 0.92
Dog temp. begin	0.00 -0.01 0.65	0.00 0.00 0.52	0.00 0.00 0.61	0.00 0.00 0.55	0.00 0.00 0.87
Dog temp. end	0.00 0.05 0.83	0.02 0.01 0.09	0.00 -0.01 0.74	0.04 0.03 0.01	0.00 0.00 0.22
Heart rate begin	0.00 0.00 0.53	0.00 0.00 0.52	0.02 0.01 0.07	0.00 0.00 0.47	0.00 0.00 0.10
Heart rate end	0.00 -0.01 0.92	0.00 0.00 0.52	0.00 -0.01 0.85	0.01 0.00 0.25	0.00 0.00 0.18
Mean dog temp.	0.02 0.02 0.09	0.01 0.01 0.13	0.00 -0.01 0.97	0.01 0.01 0.11	0.00 0.00 0.44
Mean heart rate	0.00 -0.01 0.76	0.00 0.00 0.45	0.00 0.00 0.42	0.01 0.00 0.32	0.00 0.00 0.11
Change in dog temp.	0.04 0.03 0.02	0.00 0.00 0.40	0.00 0.00 0.54	0.04 0.03 0.01	0.00 0.00 0.27
Change in heart rate	0.00 0.00 0.51	0.00 -0.01 0.97	0.01 0.01 0.09	0.01 0.00 0.35	0.00 0.00 0.88
Total duration	0.00 -0.01 0.83	0.01 0.00 0.21	0.00 0.00 0.62	0.00 0.00 0.51	0.00 0.00 0.98
Daily search duration	0.25 0.01 <0.01	0.00 -0.02 0.84	0.01 0.00 0.51	0.01 0.00 0.51	0.26 0.26 <0.01
Env. Temp. begin	0.05 0.04 0.01	0.01 0.01 0.12	0.00 0.00 0.38	0.01 0.00 0.22	0.01 0.00 0.01

Env. Temp. end	0.05 0.05 0.01	0.03 0.02 0.05	0.00 0.00 0.61	0.01 0.00 0.33	0.01 0.01 0.01
Mean env. Temp.	0..06 0.05 0.01	0.02 0.01 0.08	0.00 0.00 0.51	0.01 0.00 0.35	0.01 0.01 0.01
Change in env. Temp.	0.00 -0.01 0.59	0.00 -0.01 0.68	0.01 0.00 0.28	0.00 -0.01 0.79	0.00 0.00 0.86
Humidity begin	0.00 -0.01 0.79	0.00 0.00 0.49	0.00 0.00 0.56	0.01 0.00 0.31	0.00 0.00 0.83
Humidity end	0.00 -0.01 0.69	0.00 -0.01 0.69	0.00 -0.01 0.80	0.00 0.00 0.41	0.00 0.00 0.86
Mean humidity	0.00 -0.01 0.73	0.00 0.50 <0.01	0.00 -0.01 0.64	0.00 0.00 0.36	0.00 0.00 0.78
Change in humidity	0.00 -0.01 0.84	0.00 0.00 0.27	0.00 -0.01 0.86	0.00 -0.01 0.88	0.00 0.00 0.55
Search number	0.00 -0.01 0.99	0.00 -0.01 0.80	0.00 -0.01 0.84	0.00 -0.01 .092	0.00 0.00 0.95
Number of searches	0.31 0.29 <0.01	0.41 0.40 <0.01	0.28 0.27 <0.01	0.27 0.26 <0.01	0.32 0.32 <0.01

2.0 Number of false alarms

	Booga	Marco	Sadi	Sam	Alldogs
# of targets	0.00 0.00 0.57	0.01 0.01 0.11	0.00 0.00 0.41	0.00 -0.01 0.85	0.00 0.00 0.39
Minutes to first hit	0.04 0.03 0.02	0.00 0.00 0.55	0.00 0.00 0.55	0.00 0.00 0.64	0.00 0.00 0.19
Minutes to first FA	0.00 -0.04 0.73	0.00 -0.06 .078	0.02 -0.01 0.37	0.07 0.04 0.12	0.02 0.01 0.15
Dog temp. begin	0.01 0.00 0.20	0.01 0.00 0.28	0.00 0.00 0.71	0.01 0.00 0.19	0.00 0.00 0.83
Dog temp. end	0.00 0.00 0.56	0.01 0.01 0.17	0.00 0.00 0.31	0.00 0.00 0.39	0.00 0.00 0.06
Heart rate begin	0.00 0.00 0.52	0.00 -0.01 0.96	0.00 0.00 0.83	0.00 0.00 0.76	0.00 0.00 0.76
Heart rate end	0.00 -0.01 0.65	0.00 -0.01 0.76	0.00 0.00 0.57	0.00 0.00 0.32	0.00 0.00 0.39
Mean dog temp.	0.00 -0.01 0.68	0.02 0.01 0.10	0.00 0.00 0.51	0.00 0.00 0.38	0.00 0.00 0.31

Mean heart rate	0.00 0.00 0.59	0.0 -0.02 0.84	0.00 -0.01 0.88	0.00 0.00 0.64	0.00 0.00 0.85
Change in dog temp.	0.01 0.01 0.18	0.00 -0.01 0.86	0.00 0.00 0.41	0.00 0.00 0.62	0.00 0.00 0.06
Change in heart rate	0.00 -0.01 0.99	0.00 -0.02 0.77	0.00 0.00 0.40	0.01 0.00 0.19	0.00 0.00 0.14
Total duration	0.01 0.01 0.16	0.00 -0.01 0.76	0.04 0.03 <0.01	0.00 0.00 0.63	0.01 0.01 0.01
Daily search duration	0.09 0.07 0.03	0.00 -0.02 0.96	0.00 0.03 0.12	0.04 0.03 0.10	0.04 0.03 <0.01
Env. Temp. begin	0.00 -0.01 0.96	0.00 0.00 0.46	0.00 0.00 0.50	0.00 0.00 0.51	0.00 0.00 0.63
Env. Temp. end	0.00 -0.01 0.97	0.00 0.00 0.58	0.00 0.00 0.70	0.00 0.00 0.64	0.00 0.00 0.84
Mean env. Temp.	0.00 -0.01 0.99	0.00 0.00 0.54	0.00 0.00 0.63	0.00 0.00 0.56	0.00 0.00 0.74
Change in env. Temp.	0.00 -0.01 0.84	0.00 0.00 0.51	0.00 0.00 0.50	0.00 0.00 0.52	0.00 0.00 0.36
Humidity begin	0.01 0.00 0.22	0.00 -0.01 0.88	0.00 0.00 0.75	0.00 0.00 0.39	0.00 0.00 0.43
Humidity end	0.02 0.01 0.10	0.00 -0.01 0.74	0.00 0.00 0.36	0.00 -0.01 0.79	0.00 0.00 0.27
Mean humidity	0.02 0.01 0.14	0.00 -0.01 0.73	0.00 0.00 0.40	0.00 0.00 0.55	0.00 0.00 0.22
Change in humidity	0.00 0.00 0.46	0.00 -0.01 0.99	0.00 -0.01 0.82	0.01 0.00 0.26	0.00 0.00 0.66
Number of searches	0.03 0.01 0.20	0.02 0.01 0.09	0.05 0.03 0.08	0.02 0.02 0.03	0.04 0.04 <0.01

3.0 Number of errors

	Booga	Marco	Sadi	Sam	Alldogs
Minutes to first hit	0.01 0.00 0.24	0.07 0.06 <0.01	0.01 0.00 0.25	0.01 0.00 0.26	0.02 0.01 <0.01
Minutes to first FA	0.02 -0.02 0.51	0.25 0.23 0.05	0.02 -0.01 0.45	0.01 -0.02 0.61	0.00 -0.01 0.78
Dog temp. begin	0.00 -0.01 0.97	0.00 -0.01 0.76	0.01 0.00 0.16	0.00 0.00 0.45	0.00 0.00 0.15

Dog temp. end	0.03 0.02 0.05	0.00 -0.01 0.72	0.00 0.00 0.44	0.02 0.01 0.07	0.00 0.00 0.45
Heart rate begin	0.00 -0.01 0.86	0.01 0.00 0.27	0.02 0.01 0.07	0.00 0.00 0.62	0.01 0.01 0.02
Heart rate end	0.00 -0.01 0.77	0.00 0.00 0.64	0.00 0.00 0.36	0.02 0.01 0.09	0.01 0.01 0.01
Mean dog temp.	0.01 0.01 0.16	0.00 -0.01 0.88	0.01 0.00 0.24	0.01 0.01 0.13	0.00 0.00 0.25
Mean dog heart rate	0.00 -0.01 0.88	0.00 0.00 0.35	0.01 0.00 0.19	0.01 0.00 0.21	0.01 0.01 0.01
Change in dog temp.	0.02 0.01 0.13	0.00 0.00 0.46	0.00 0.00 0.88	0.01 0.01 0.16	0.00 0.00 0.87
Change in heart rate	0.00 -0.01 0.67	0.00 0.00 0.58	0.00 0.00 0.69	0.01 0.01 0.10	0.00 0.00 0.31
Total duration	0.03 0.02 0.03	0.03 0.02 0.02	0.04 0.04 0.00	0.01 0.00 0.24	0.03 0.02 0.00
Daily search duration	0.20 0.19 <0.01	0.10 0.08 0.02	0.12 0.10 0.01	0.18 0.00 0.24	0.15 0.15 <0.01
Env. Temp. begin	0.01 0.01 0.14	0.01 0.00 0.25	0.00 0.00 0.60	0.00 -0.01 0.79	0.00 0.00 0.36
Env. Temp. end	0.02 0.01 0.14	0.01 0.01 0.17	0.00 0.00 0.49	0.00 -0.01 0.85	0.00 0.00 0.31
Mean env. Temp.	0.02 0.01 0.14	0.01 0.00 0.18	0.00 0.00 0.58	0.00 0.00 0.71	0.00 0.00 0.35
Change in env. Temp.	0.00 -0.01 0.76	0.00 -0.01 0.88	0.00 0.00 0.45	0.00 0.00 0.33	0.00 0.00 0.59
Humidity begin	0.00 0.00 0.57	0.00 0.00 0.55	0.00 0.00 0.71	0.00 -0.01 0.83	0.00 0.00 0.52
Humidity end	0.00 0.00 0.44	0.00 -0.01 0.80	0.00 -0.01 0.90	0.00 -0.01 0.93	0.00 0.00 0.56
Mean humidity	0.00 0.00 0.49	0.00 -0.01 0.76	0.00 0.00 0.58	0.00 -0.01 0.94	0.00 0.00 0.46
Change in humidity	0.00 -0.01 0.74	0.00 -0.01 0.90	0.00 -0.01 0.92	0.00 0.00 0.53	0.00 0.00 0.80
Number of searches	0.12 0.10 0.01	0.00 0.17 0.02	0.08 0.06 0.03	0.00 0.00 0.34	0.10 0.09 <0.01

4.0 Beginning dog temperature

	Booga	Marco	Sadi	Sam	Alldogs
Heart rate begin	0.19 0.19 <0.01	0.14 0.13 0.00	0.31 0.31 <0.01	0.04 0.03 0.01	0.20 0.20 <0.01
Heart rate end	0.00 -0.01 0.83	0.00 0.00 0.53	0.08 0.08 0.00	0.00 0.00 0.38	0.02 0.02 0.00
Mean heart rate	0.06 0.06 <0.01	0.03 0.02 0.02	0.24 0.23 <0.01	0.02 0.01 0.06	0.11 0.11 <0.01
Change in heart rate	0.13 0.12 <0.01	0.14 0.13 <0.01	0.05 0.05 <0.01	0.00 0.00 0.38	0.06 0.06 <0.01
Total duration	0.05 0.04 0.01	0.04 0.03 0.01	0.04 0.03 0.01	0.08 0.07 <0.01	0.04 0.05 <0.01
Env. Temp. begin	0.01 0.01 0.14	0.00 0.00 0.51	0.00 0.00 0.53	0.08 0.08 <0.01	0.01 0.01 0.02
Env. Temp. end	0.01 0.00 0.26	0.00 0.00 0.52	0.00 0.00 0.57	0.04 0.04 0.01	0.00 0.00 0.08
Mean env. Temp.	0.01 0.00 0.22	0.00 0.00 0.53	0.00 0.00 0.56	0.07 0.06 <0.01	0.01 0.00 0.04
Change in env. Temp.	0.00 -0.01 0.64	0.00 0.00 0.56	0.00 -0.01 0.94	0.07 0.06 <0.01	0.01 0.01 0.01
Humidity begin	0.01 0.00 0.25	0.00 0.00 0.94	0.00 0.00 0.64	0.00 -0.01 0.80	0.00 0.00 0.73
Humidity end	0.00 -0.01 0.57	0.00 -0.01 0.97	0.00 0.00 0.74	0.00 -0.01 0.94	0.00 0.00 0.60
Mean humidity	0.00 0.00 0.44	0.00 -0.01 0.95	0.00 -0.01 0.97	0.00 -0.01 0.93	0.00 0.00 0.80
Change in humidity	0.00 0.00 0.53	0.00 0.00 0.67	0.01 0.00 0.17	0.00 0.00 0.56	0.00 0.00 0.22
Search number	0.00 0.00 0.58	0.04 0.04 <0.01	0.00 0.00 0.74	0.06 0.06 <0.01	0.01 0.01 <0.01

5.0 Ending dog temperature

	Booga	Marco	Sadi	Sam	Alldogs
Heart rate begin	0.00 -0.01 0.88	0.00 0.00 0.46	0.00 -0.01 0.94	0.01 0.01 0.11	0.00 0.00 0.09
Heart rate end	0.10 0.10 <0.01	0.08 0.08 <0.01	0.10 0.09 <0.01	0.23 0.22 <0.01	0.14 0.15 <0.01

Mean heart rate	0.04 0.04 0.01	0.04 0.04 0.01	0.03 0.02 0.02	0.08 0.08 <0.01	0.07 0.07 <0.01
Change in heart rate	0.10 0.09 <0.01	0.05 0.05 <0.01	0.11 0.10 <0.01	0.31 0.30 <0.01	0.12 0.12 <0.01
Total duration	0.00 -0.01 0.69	0.00 0.00 0.45	0.00 -0.01 0.98	0.00 0.00 0.39	0.00 0.00 0.88
Env. Temp. begin	0.40 0.40 <0.01	0.36 0.35 <0.01	0.09 0.09 <0.01	0.22 0.22 <0.01	0.18 0.19 <0.01
Env. Temp end	0.46 0.45 <0.01	0.37 0.37 <0.01	0.07 0.07 <0.01	0.30 0.30 <0.01	0.21 0.21 <0.01
Mean env. Temp.	0.45 0.44 <0.01	0.37 0.37 <0.01	0.08 0.07 <0.01	0.27 0.27 <0.01	0.20 0.20 <0.01
Change in env. Temp.	0.08 0.08 <0.01	0.00 0.00 0.60	0.01 0.01 0.11	0.05 0.04 <0.01	0.01 0.01 0.01
Humidity begin	0.00 -0.01 0.74	0.00 0.00 0.64	0.04 0.03 0.01	0.00 0.00 0.39	0.00 0.00 0.30
Humidity end	0.04 0.04 0.01	0.00 0.00 0.62	0.04 0.04 0.00	0.04 0.03 0.02	0.01 0.01 <0.01
Mean humidity	0.02 0.02 0.08	0.00 -0.01 0.92	0.04 0.03 0.01	0.02 0.01 0.08	0.01 0.01 0.04
Change in humidity	0.07 0.06 0.00	0.04 0.03 0.02	0.00 0.00 0.54	0.04 0.04 0.01	0.03 0.02 <0.01
Search number	0.06 0.06 <0.01	0.00 -0.01 0.91	0.01 0.00 0.16	0.00 0.00 0.70	0.01 0.01 0.03

6.0 Beginning heart rate

	Booga	Marco	Sadi	Sam	Alldogs
Mean dog temp.	0.09 0.08 <0.01	0.07 0.06 <0.01	0.12 0.11 <0.01	0.00 -0.01 0.87	0.10 0.10 <0.01
Change in dog temp.	0.10 0.09 <0.01	0.05 0.05 <0.01	0.17 0.16 <0.01	0.05 0.04 <0.01	0.07 0.07 <0.01
Total duration	0.01 0.00 0.28	0.00 -0.01 0.83	0.03 0.02 0.02	0.02 0.02 0.05	0.02 0.02 <0.01
Env. Temp. begin	0.00 -0.01 0.73	0.01 0.01 0.11	0.08 0.08 <0.01	0.03 0.02 0.03	0.03 0.03 <0.01
Env. Temp. end	0.00 0.00 0.38	0.01 0.01 0.11	0.08 0.08 <0.01	0.03 0.02 0.03	0.03 0.03 <0.01

Mean env. Temp.	0.00 0.00 0.51	0.01 0.01 0.12	0.08 0.08 <0.01	0.03 0.02 0.03	0.03 0.03 <0.01
Change in env. Temp.	0.03 0.02 0.05	0.00 -0.01 0.80	0.00 0.00 0.59	0.00 0.00 0.70	0.00 0.00 0.20
Humidity begin	0.00 -0.01 0.82	0.01 0.01 0.12	0.00 0.00 0.59	0.01 0.01 0.10	0.00 0.00 0.11
Humidity end	0.00 -0.01 0.74	0.01 0.00 0.30	0.01 0.00 0.19	0.01 0.00 0.18	0.00 0.00 0.28
Mean humidity	0.00 -0.01 0.84	0.01 0.00 0.18	0.00 0.00 0.33	0.01 0.01 0.14	0.00 0.00 0.16
Change in humidity	0.00 -0.01 0.62	0.01 0.00 0.31	0.00 0.00 0.38	0.00 -0.01 0.77	0.00 0.00 0.50

7.0 Ending heart rate

	Booga	Marco	Sadi	Sam	Alldogs
Mean dog temp.	0.06 0.05 <0.01	0.02 0.01 0.07	0.16 0.16 <0.01	0.17 0.16 <0.01	0.12 0.12 <0.01
Change in dog temp.	0.06 0.05 <0.01	0.07 0.07 <0.01	0.00 0.00 0.83	0.14 0.14 <0.01	0.04 0.04 <0.01
Total duration	0.01 0.00 0.29	0.00 0.00 0.40	0.00 0.00 0.65	0.00 0.00 0.35	0.00 0.00 0.58
Env. Temp. begin	0.01 0.00 0.37	0.00 0.00 0.50	0.02 0.01 0.07	0.01 0.00 0.19	0.00 0.00 0.98
Env. Temp end	0.01 0.00 0.25	0.00 0.00 0.49	0.02 0.01 0.09	0.03 0.03 0.02	0.00 0.00 0.52
Mean env. Temp	0.01 0.00 0.28	0.00 0.00 0.48	0.02 0.01 0.09	0.02 0.02 0.06	0.00 0.00 0.66
Change in env. Temp.	0.00 0.00 0.43	0.00 -0.01 0.83	0.00 0.00 0.62	0.05 0.04 0.01	0.01 0.00 0.05
Humidity begin	0.00 -0.01 0.58	0.00 0.00 0.49	0.00 -0.01 0.93	0.00 0.00 0.38	0.00 0.00 0.65
Humidity end	0.01 0.00 0.21	0.01 0.00 0.23	0.01 0.01 0.16	0.00 0.00 0.63	0.00 0.00 0.20
Mean humidity	0.01 0.00 0.27	0.01 0.00 0.29	0.00 0.00 0.54	0.00 -0.01 0.91	0.00 0.00 0.59
Change in humidity	0.00 -0.01 0.56	0.00 0.00 0.49	0.02 0.02 0.03	0.03 0.02 0.03	0.01 0.01 0.02

Search number	0.04 0.03 0.02	0.01 0.00 0.29	0.00 0.00 0.99	0.00 0.00 0.69	0.00 0.00 0.15

8.0 Total duration

	Booga	Marco	Sadi	Sam	Alldogs
Env. Temp begin	0.00 -0.01 1.00	0.00 -0.01 0.95	0.00 0.00 0.92	0.00 0.00 0.35	0.00 0.00 0.79
Env. Temp. end	0.00 0.00 0.48	0.00 0.00 0.50	0.00 0.00 0.41	0.00 -0.01 0.95	0.00 0.00 0.20
Mean env. Temp.	0.00 -0.01 0.65	0.00 -0.01 0.71	0.00 0.00 0.66	0.00 0.00 0.71	0.00 0.00 0.56
Change in env. Temp.	0.04 0.03 0.03	0.04 0.04 0.01	0.08 0.08 <0.01	0.04 0.03 0.01	0.04 0.04 <0.01
Humidity begin	0.00 -0.01 0.74	0.00 0.00 0.52	0.01 0.01 0.11	0.02 0.01 0.06	0.01 0.00 0.04
Humidity end	0.00 -0.01 0.62	0.00 0.00 0.68	0.00 0.00 0.53	0.00 -0.01 0.76	0.00 0.00 0.80
Mean humidity	0.00 -0.01 0.62	0.00 -0.01 1.00	0.01 0.00 0.24	0.01 0.00 0.31	0.00 0.00 0.25
Change in humidity	0.00 -0.01 0.98	0.02 0.01 0.10	0.02 0.01 0.06	0.04 0.03 0.01	0.01 0.01 <0.01
Search number	0.06 0.05 <0.01	0.12 0.11 <0.01	0.14 0.14 <0.01	0.10 0.10 <0.01	0.10 0.10 <0.01

9.0 Daily search duration

	Booga	Marco	Sadi	Sam	Alldogs
Mean env. Temp.	0.26 0.24 <0.01	0.00 -0.01 0.71	0.03 0.02 0.17	0.01 -0.01 0.54	0.06 0.06 <0.01
Mean humidity	0.00 -0.02 0.78	0.00 -0.01 1.00	0.01 -0.01 0.44	0.00 -0.02 0.88	0.00 0.00 0.98