Characterizing Sustained Attention Task Performance by Dogs

by

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Auburn, Alabama
December 9, 2023

Keywords: Sustained attention, signal detection, vigilance, canine cognition

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Abstract

A common finding in studies of sustained attention is that performance on these types of tasks is subject to fluctuations across the duration of the task. Several task-related factors have been consistently demonstrated to impact performance on these tasks, including: signal probability, event rate, background noise, and signal predictability. This phenomenon has been extensively studied in both humans and rats, but to date, there has been no systematic investigation into the sustained attention performance abilities of dogs. The present study evaluated canine sustained attention performance on an olfactory signal detection task. A baseline of detection performance for signal events of differing intensity levels was established, with dogs performing at overall high levels across all signal intensities. Dogs were then tested under conditions known to affect sustained attention task performance in humans and rats, including extended duration, reduced signal discriminability, reduced extrinsic motivation, and reduced signal probability. Overall, dogs' performance was largely unaffected by any task manipulations, suggesting that dogs' sustained attention abilities are resilient under the given testing parameters. However, this study is limited by small sample size and varying testing structures used across dogs, preventing any strong conclusions about dogs' sustained attention abilities. The present study has conceptual significance, by providing an opportunity to compare sustained attention and signal detection performance across species, as well as the potential to advance knowledge in practical applications to the work of operational detection dogs.

Acknowledgments

Funding for this study was provided by grants from Auburn University's Department of Psychological Sciences, the Association of Professional Dog Trainers, and from the Animal Behavior Society. We thank Canine Performance Sciences for their provision of dogs and logistical support, as well as the members of Auburn University's Comparative Cognition laboratory for their assistance with data collection.

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List of Abbreviations

AUCVM	Auburn University College of Veterinary Medicine
ITI	Intertrial interval
VI	Vigilance Index

Introduction

Sustained attention has been described as a process of attention characterized by the ability to detect rare and infrequent signals across a span of time (Sarter, Givens, & Bruno, 2001). More simply, it refers to the ability of an individual to maintain alertness for an extended period of time (Ballard, 1996). An important component of sustained attention is vigilance, which is a physical or mental state of readiness to detect and respond to a stimulus (Ballard, 1996). Common across studies of sustained attention is the finding that performance tends to degrade with time spent on task, a phenomenon referred to as vigilance decrement (Warm, Parasuraman, & Matthews, 2008). This phenomenon is particularly evident in tasks involving signal probabilities of 10% or less. Performance on such tasks has been shown to degrade within the first 15-minutes of a watch-period but can occur as rapidly as within the first five minutes of task engagement based on demands of the task (Ballard, 1996; Bushnell, 1999).

Traditionally, this inconsistency in performance has been attributed to two competing theories: the resource depletion (overload) theory, which suggests that the continuous nature of sustained attention tasks exhausts the availability of cognitive resources required to perform the task, or the mindlessness (underload) theory, which suggests that the under-stimulating nature of the task results in a reallocation of attentional resources away from the task (Fortenbaugh, DeGutis, & Esterman, 2017; Helton & Warm, 2008; Manly, Robertson, Galloway, & Hawkins, 1999). More recently, new theories have been proposed that further account for the role of cognitive control as it pertains to sustained attention task performance. These theories include the resource-control theory and the opportunity-cost model. The resource-control theory suggests that there is a bias for attentional resources to be directed towards a default state of mind-wandering, such that failure to sustain attention can be attributed to unintentional wandering of the mind. The opportunity-cost model expounds upon resource-control theory, further providing an explanation for why a default mode of mind-wandering is preferred. This model suggests that availability of alternative tasks with a higher subjective value results in greater perceived effort with engaging in the current task, thus failure to sustain attention can be attributed to intentional mind-wandering. This theory also emphasizes the role of motivation in maintaining sustained attention performance, as opposed to diminishing cognitive resources (Esterman & Rothlein, 2019; Fortenbaugh, DeGutis, & Esterman, 2017). Table 1 provides an overview of these theories.

Table 1

Theories of Sustained Attention Task Performance

THEORY	DESCRIPTION
Resource Depletion Theory (Overload)	Decline in performance is due to exhaustion of cognitive resources
Mindlessness Theory (Underload)	Decline in performance is due to under-stimulating nature of the task, resulting in a reallocation of attentional resources away from the task
Resource-Control Theory	Decline in performance is due to unintentional mind-wandering due to default attentional bias towards mind-wandering
Opportunity-Cost Model	Decline in performance due to intentional redirection of attention to other available alternatives with higher perceived value

Task-related factors have been consistently demonstrated to influence performance levels on tasks of sustained attention in humans. These factors can be divided into factors relating to the stimulus itself, such as signal intensity and/or duration, as well as factors relating to the relationships between stimuli, such as event rate and/or probability (Dember & Warm, 1979). Specifically, tasks involving high event rates, low signal salience, and temporal/spatial uncertainty of signal events tend to generate poorer performance (McGaughy & Sarter, 1995). Studies of sustained attention in animals have demonstrated a limited capacity of attention characterized by performance fluctuations and decrements like those observed in humans (Dukas, 2004). Sustained attention, as it typically applies to animal models, involves monitoring for predators and detection of cryptic prey (Dukas & Clark, 1995). Limitations of attention while engaging in these behaviors have been demonstrated such that investing greater attention to prey detection results in a decreased ability to monitor for predators, and vice versa (Dukas & Kamil, 2000).

Laboratory models of sustained attention performance have also evaluated attentional capacity in animals utilizing signal detection tasks. Studies of sustained attention performance by rats have demonstrated changes in performance subject to the same task-related factors known to affect sustained attention performance in humans, such that high event rate, low signal salience, and unpredictable signals result in lower levels of performance (Bushnell, 1999 ;McGaughy & Sarter, 1995). Further, when evaluated under similar testing procedures, rat and human performance of a signal detection task was found to be similarly influenced by manipulations of trial rate and signal intensity, demonstrating a generality of these effects and suggesting utilization of similar control processes across species (Bushnell, Benignus, & Case, 2003). Decreases in performance across time, or vigilance decrement, have also been observed in species such as rats and jumping spiders, however, induction of vigilance decrement utilizing these methods has been inconsistent (Bushnell, 1999; Humphrey, Helton, Bedoya, Dolev, & Nelson, 2018; McGaughy & Sarter, 1995; Melrose, Nelson, Dolev, & Helton, 2019).

It is widely accepted that dogs are subject to the vigilance decrement phenomenon, as evidenced by time and/or context dependent declines in task performance by detection dogs (e.g., Aviles-Rosa et al. 2022; Gazit et al, 2005; Porritt et al., 2015). Recent work has begun to investigate strategies to maintain performance levels in contexts in which chances of encountering target stimuli are low, such as through use of noncontingent reward or implementing training schedules with progressively lower target frequencies (Aviles-Rosa et al., 2023; Dechant et al., 2023; Dechant et al. 2023). However, characterization of sustained attention abilities in dogs as they apply to vigilance behaviors, as well as factors influencing these behaviors, remain underexplored.

Characterization of dogs' sustained attention abilities has practical applications to the work of detection dogs. The work performed by detection dogs deployed in the field often represents a sustained attention type task, requiring constant monitoring of the environment for an infrequent and unpredictable signal. Thus, it is important to understand factors that might affect dogs' performance of these types of tasks. Additionally, characterization of dogs' sustained attention abilities has important comparative value, allowing cross-species comparisons with both humans and rats. The proposed study will consist of a series of experiments to evaluate sustained attention abilities of dogs and factors that may affect it by adapting the procedure used by McGaughy and Sarter (1995) to investigate sustained attention in rats.

McGaughy and Sarter (1995) utilized a visual signal detection task, establishing a baseline detection rate for lights of three different intensities, as well as blank trials in which no light was present. After establishing this base rate of performance, manipulations known to affect sustained attention performance in humans were introduced, such that signal salience, event rate, and event predictability were altered. The following two experiments used this procedure utilizing olfactory signal events. In keeping with McGaughy and Sarter, Experiment 1 established baseline levels of detection performance for differing intensities of the odor amyl acetate. In Experiment 2, dogs were tested under a variety of conditions expected to negatively impact dogs' sustained attention performance, including extended test session duration, reduced signal event probability, reduced extrinsic motivation by reducing the availability of reward for correct responses, and increased olfactory background noise present in the testing room.

The present study differed in a few ways from McGaughy and Sarter's in order to best facilitate the task utilizing olfaction as the target sensory modality and to make adjustments for the use of canine subjects. Rather than being contained in an operant chamber with response levers as rats were, dogs were contained in an enclosure and trained to offer differential responses for signal versus nonsignal trials, as opposed to lever pressing. Further, McGaughy and Sarter's experiment included evaluation of the effects of event rate and event asynchrony on detection performance. However, these manipulations were not included in the present study due to logistical limitations including subject availability and time constraints. Despite these differences, it was hypothesized that dogs would perform similarly to both rats and humans tested in this paradigm, such that performance would be degraded by reduced signal probability, task motivation, and signal discriminability. Table 2 presents the expected outcomes for each manipulation based on the four theories previously described.

Table 2

Expected Effects of Task Manipulations by Sustained Attention Theory

Theory	Experiment 1: Baseline	Experiment 2: Sustained Attention	Experiment 2: Vigilance & Motivation	Experiment 2: Background Noise
Resource Depletion Theory (Overload)	Decrease in performance over time with steeper decrement for low intensity signals	Decrease in performance over time with steeper decrement in later trial blocks and for low intensity signals	Decreasing performance over time in both treat and no treat conditions	Steeper rate of decrement observed across all signal intensities than baseline
Mindlessness Theory (Underload)	Decrease in performance over time across all trial types, possibly greater performance on low intensity signals	Decrease in performance over time across all trial types, especially evident in the second half of the test	Decrease in performance over time with greater decrease in no treat condition	Performance levels should be maintained or better due to more stimulating task
Resource-Control Theory	Fluctuating performance levels	Fluctuating performance levels	Fluctuating but overall decreasing performance over time in both treat and no treat conditions	Fluctuating performance
Opportunity-Cost Model	Fluctuating performance levels	Fluctuating performance levels	Greater fluctuations in performance for no treat condition	Fluctuating performance

Experiment 1

The purpose of Experiment 1 was to train the detection task and to establish baseline levels of signal detection performance for signals of differing intensities. Dogs were first trained to discriminate signal and nonsignal trials, then were trained to identify different intensity levels of the signal odor.

Method

Subjects

Subjects were five (3F/2M) adult (*M* age = 3.4 years; SEM = 0.51) Labrador retrievers bred by Auburn University's Canine Performance Sciences program. Two dogs were unable to complete testing, one due to inability to learn the task and one due to an unrelated injury that prevented further training. Thus, the final sample was 3 dogs (2F/1M; *M* age = 3.7 years, SEM = 0.89): Karen (female, 2 years old), Roxy (female, 4 years old), Stan (male, 5 years old). All dogs had received extensive prior training in olfactory detection work (for a complete outline of dogs' training history, see Lazarowski et al., 2018). Dogs were housed in individual indoor/outdoor runs within the kennel complex at the Auburn University College of Veterinary Medicine (AUCVM). All animal activity was approved and monitored by the Auburn University Institutional Animal and Care Use Committee (#2022-4029) in accordance with the U.S. Animal Welfare Act. The AUCVM is an Association for Assessment and Accreditation of Laboratory Animal Care International accredited facility.

Stimuli

A nonsignal event consisted of mineral oil. A signal event consisted of dilutions of amyl acetate in mineral oil of varying concentrations. The dilutions of amyl acetate used were dependent on each individual dog's detection abilities and ranged from 10^{-5} to 10^{-15}. Amyl acetate was chosen as the signal event odor due to its known canine olfactory detection threshold range as established by Concha et al., 2019.

Odors were presented in stainless steel powdered sugar shakers (RSVP International Endurance Kitchen Shaker), hereafter referred to as tins. Tins were 3.75-inches tall and 2.8-inches in diameter with fine mesh lids. One milliliter of either mineral oil or amyl acetate dilution was applied to a cotton round. The cotton round was then placed in the bottom of a tin and a plastic cap was fitted over the mesh lid to prevent odor from escaping. Cotton rounds were not replaced during baseline length sessions but were replaced at the midpoint of extended sessions.

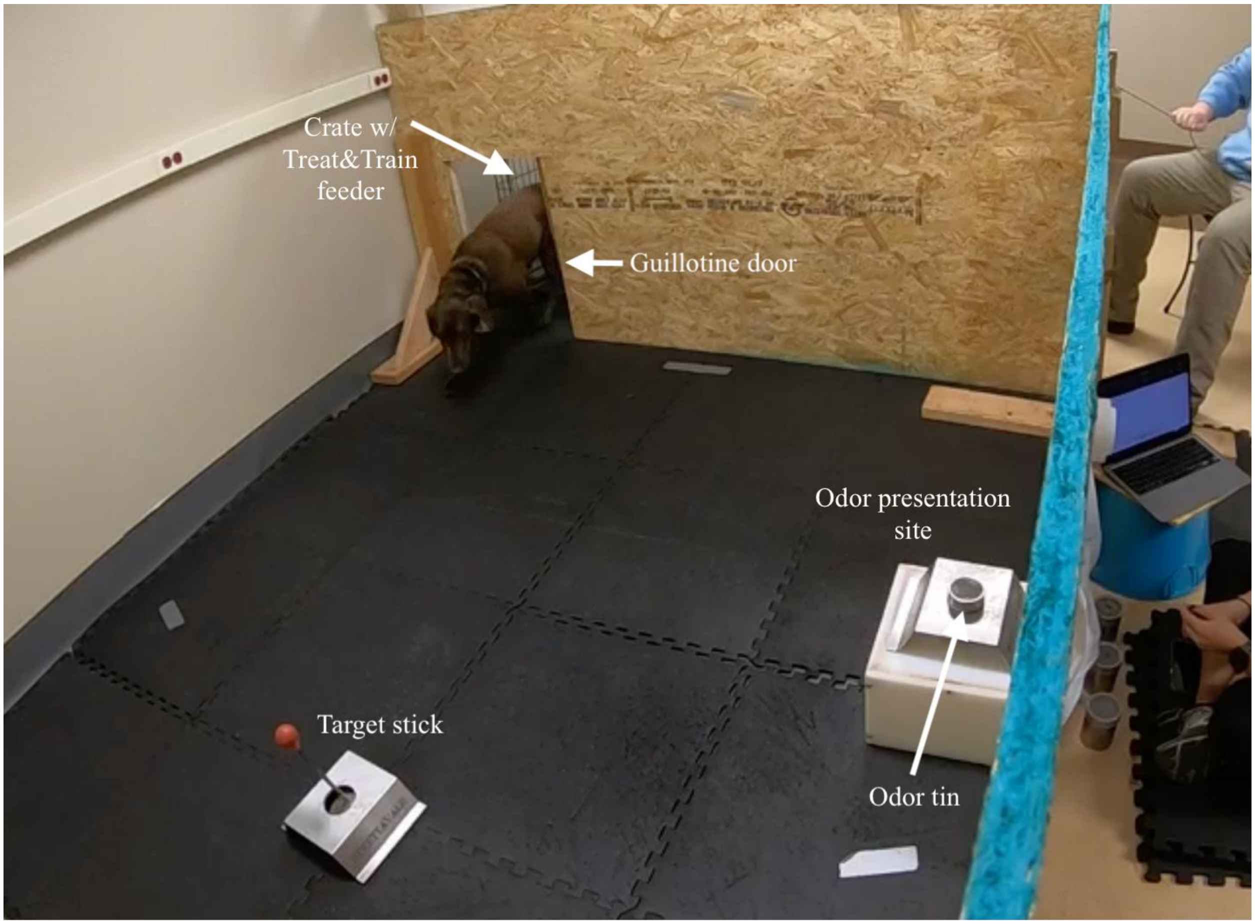
Apparatus

Dogs were enclosed in an arena approximately 8-ft by 8-ft (see Figure 1). Two walls of this arena were the walls of the testing room. The other two walls were made of plywood secured together and fitted to the walls of the testing room. The floor of the arena was made up of foam gym floor tiles (Eagle Mat and Floor Products Everlast Mats). One of the plywood walls had a large cutout with a guillotine door attached. A large wire crate was put in front of this opening such that the crate could be pressed flush against the wall and the guillotine door could be used to allow the dog to enter and exit the arena from the crate. A PetSafe Manners Minder Treat&Train machine (model #MM-RR-SYS) was located at the back of the crate to administer food reward following correct responses.

The second plywood wall had a 1-ft by 1-ft square cut out of the middle of it. Directly in front of this cutout inside the arena was the odor presentation site. This site consisted of a metal stand with a hole in the middle into which the odor tins could be placed. This stand sat atop a plastic box that was 10-cm tall such that it was roughly nose height for the dogs. Outside of the arena, this cutout was covered with a piece of plastic shower curtain. The experimenter sat behind this covering and placed the tins in the arena between each trial. A target stick was positioned approximately 3-feet to the right of the odor presentation site. A GoPro Hero 8 camera was fixed above the odor presentation site to record each session.

Figure 1

Testing Apparatus



Note. Image of the testing apparatus.

Procedure

Target Stick Training.

Dogs were initially trained to touch a target stick through a shaping procedure in which successive approximations of the response were rewarded until dogs were fully proficient in touching the target stick to receive a food reward from a Treat&Train machine. This training occurred in a fenced-in parking area outside of the testing building. Once dogs demonstrated proficiency in touching the target stick by continuously moving between the target stick and the Treat&Train machine, training moved to the testing location.

Discrimination Training

Sessions consisted of 160 trials (162 for Karen). There were two trial types: signal and nonsignal. Dogs were trained to exit the crate, sample at the odor presentation site to determine if the signal (target odor) was present or absent, and return to the crate. All dogs were previously trained to sit in response to the presence of amyl acetate, therefore on signal trials when this odor was present, dogs were required to sit as the correct response. For nonsignal trials where only mineral oil was present, dogs were required to move within 6-inches of the target stick. All correct responses resulted in immediate food reward consisting of approximately 3-5 pieces of kibble administered by a Treat&Train located at the back of the crate. Incorrect responses resulted in a verbal "no" and termination of the trial. If a dog failed to respond within 15-s, the dog was called back to the crate and the trial was recorded as an error of omission. Training of the detection task occurred through a mix of shaping behaviors and pseudo-randomizing signal and nonsignal trials, such that training sheets were randomly generated but there could be no more than three of one trial type in a row, until dogs were proficient in sampling at the odor presentation site and offering the correct response.

The target odor for signal trials began as 1-ml of a high intensity dilution of 10^{-3} amyl acetate in mineral oil applied to a cotton round. Once dogs reached 80% accuracy at this level, a dilution of 10^{-5} (prepared in the same way) was added and signal events in the session were made up of 50% high intensity odor and 50% low intensity odor. Dogs were initially assisted on the lower intensity odor, with the experimenter telling the dog "sit" immediately after the dog sampled the odor port. Assistance was faded out when the dog demonstrated the ability to offer the correct response to the low odor on its own. When dogs reached 80% accuracy for the 10^{-5} dilution, 10^{-3} was removed as the high intensity odor and 10^{-7} was added as a new low intensity odor. Odor intensity was continually reduced following this pattern until performance stabilized.

Discrimination Training Adjustments

Originally, the plan was to test dogs on three levels of amyl acetate dilutions representing high, medium, and low odor intensities. Odor was reduced throughout training using the method described above until performance on the high odor intensity was 85% or greater, performance on the low odor intensity was 60-75%, and performance on the medium odor intensity was 70-85%. However, we encountered some unexpected difficulties in establishing different performance ranges across odor intensities. Dogs tended to be "all or nothing" in their responding, such that they were either nearly 100% accurate for an odor level or far below chance. Establishing variable performance ranges was difficult. This difficulty impacted our first two dogs and they were tested in different ways. One of these dogs, Karen, continued to perform at high levels despite consistently decreasing odor intensities. Eventually the decision was made to move her into testing despite her high performance levels on all three odor intensities, rather than continue training indefinitely. The second dog, Stan, exhibited performance levels like Karen's, continuing to perform at very high levels for increasingly lower intensity odors. However, eventually the low intensity odor became too low, to the point where it was too difficult for him to discriminate from the mineral oil only nonsignal trials. At this point, Stan was no longer under stimulus control to the extent that, even after months of retraining, he was unable to attain high levels of performance. He ultimately could only be tested with one, relatively high intensity odor.

Following the difficulties encountered with Karen and Stan, for the final dog Roxy, the training procedure was slightly modified. Rather than continue to provide assistance on the low odor intensity as it dropped, Roxy was assisted on its first occurrence only. Additionally, due to the difficulties in establishing variable performance ranges for three odor intensities, Roxy received only a high and low intensity target. These procedural changes were effective and the desired performance levels for both odor intensities was achieved. The odor levels used for each dog's testing can be seen in Table 3.

Table 3

Amyl Acetate Dilutions Used for Each Dog

Dog	High Odor Intensity	Medium Odor Intensity	Low Odor Intensity
Karen	10^{-7}	10^{-10}	10^{-15}
Stan	10^{-5}	n/a	n/a
Roxy	10^{-5}	n/a	10^{-7}

For all dogs, training continued until performance for the signal trial amyl acetate dilutions and the nonsignal trial mineral oil stabilized. Stable baseline performance was defined as four sessions with performance on three out of four sessions above chance levels and within a 5% range without steady increases in performance for nonsignal trials and for all signal odor intensities used (Stan's overall baseline performance is made up of one day of baseline performance due to limited subject availability). These sessions were made up of an even number of signal and nonsignal event trials, presented in pseudorandomized order such that each trial type was presented no more than three times in a row. Final session structure for each dog can be seen in Table 4. All correct responses were reinforced by food reward accompanied by a tone via Treat&Train. Incorrect responses resulted in a verbal correction, “No”, and no reward. A 20-s intertrial interval (ITI) occurred following the time of final response on the previous trial, during which the dog was held in the crate.

Table 4

Baseline Session Structure by Dog

Dog	Total Trials	Nonsignal Trials	Signal Trials	Signal Trial Makeup
Karen	162	81	81	27 high, 27 medium, 27 low
Stan	160	80	80	80 high
Roxy	160	80	80	40 high, 40 low

Data Analysis

For analysis, all baseline sessions were divided into 4 trial blocks with even numbers of nonsignal and signal trials, with signal trials made up of even numbers of all signal odor intensities used for a given dog. All sessions were live scored by an observer for correct and incorrect responses, as well as errors of omission. Additional behavioral measures were double-scored and calculated from video for each session, as well as for trial blocks within sessions. Additional behavioral measures included hits, misses, correct rejections, false alarms, errors of omission, and overall percent correct for each trial type. Overall percent correct for each trial type was calculated for each dog, excluding errors of omission. Vigilance index ($VI = (h-f)/[2*(h+f)-(h+f)^2]$) was also calculated as overall session VI (signal versus nonsignal trials) as well as for each signal odor intensity level relative to nonsignal trials, indicating a dog’s ability to discriminate between signal and nonsignal trials (McGaughy & Sarter, 1995). VI values range from -1 to +1, with a VI of 0 indicating a complete inability of the dog to discriminate between signal and nonsignal events, a VI of +1 indicating correct responding on all trials, and a VI of -1 indicating incorrect responding on all trials. Vigilance index was used as the primary measure of performance due to its sensitivity to performance on both nonsignal and signal trials. For each dog, a general linear model was used to evaluate the effects of trial block and trial type on VI. Trial types included were nonsignal (hereafter referred to as overall VI, as this value indicates discriminability between nonsignal trials and all signal odor intensities combined) and each individual signal odor intensity level. For dogs with performance collapsed across multiple baseline sessions, a general linear model was used to evaluate the effect of session number and trial type on VI. Latency was also calculated for each trial, as the amount of time between the start of the trial (from the time of the guillotine door opening fully) and the dog's final response. A general linear model was used to evaluate the effect of trial block and trial type on latency.

A subset of trials (25%) were video-scored by a secondary observer to achieve interrater reliability for performance and trial latency for both Experiment 1 and 2 combined. Inter-rater reliability was assessed using a two-way mixed effects model for consistency with fixed raters (ICC3) to assess the degree of consistency between raters. Reliability for Karen was moderate for performance, ICC = 0.6, $p < .01$, and good for latency, ICC = 0.8, $p < .01$. Reliability for Stan was excellent for performance, ICC = 0.9, $p < .01$, and good for latency, ICC = 0.8, $p < .01$. Reliability for Roxy was good for performance, ICC = 0.8, $p < .01$, and moderate for latency, ICC = 0.7, $p < .01$.

Results

Acquisition

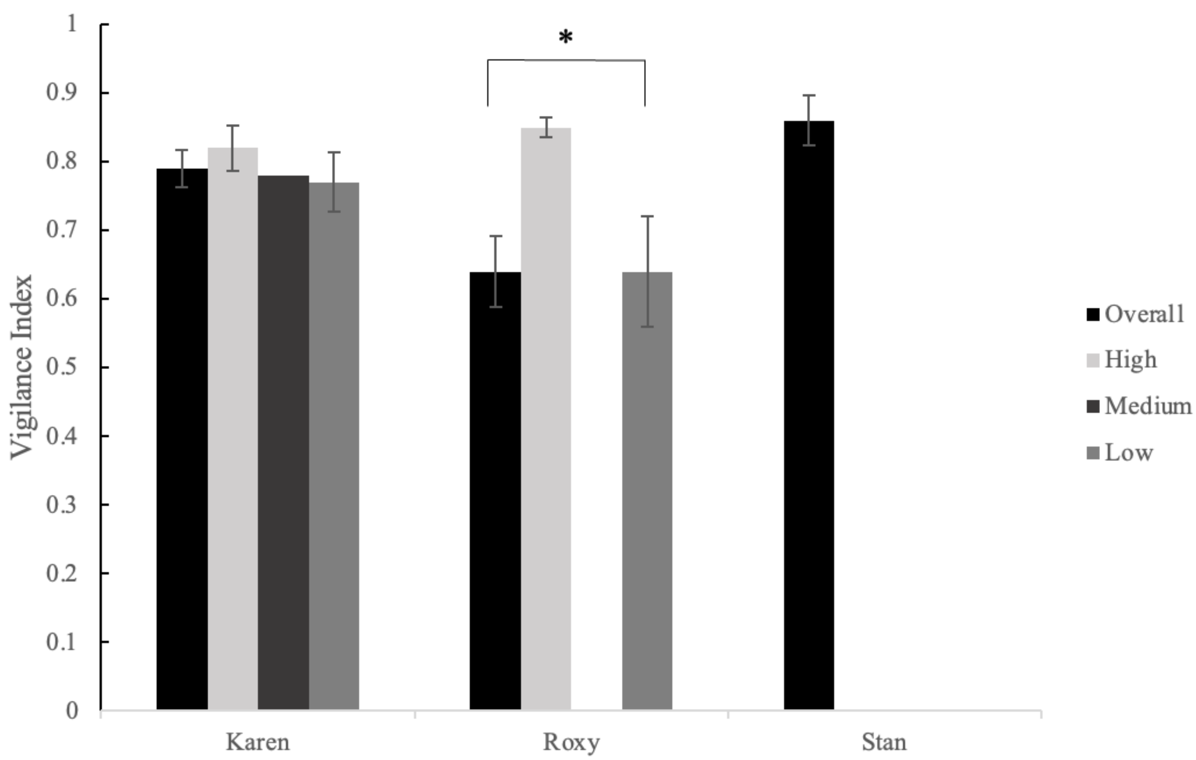
For all dogs, target stick training in which the dogs learned to touch the target stick to receive a food reward, took two sessions. The number of training sessions required to reach the discrimination training criteria varied by dog (Karen, Roxy, Stan: 50, 85, 100 sessions, respectively).

Karen

Karen's baseline performance stabilized at an average of 84% for nonsignal trials, 95% for the high signal odor, 92% for the medium signal odor, and 91% for the low signal odor. There were no errors of omission. Overall VI in this condition was 0.79, with VI for the high signal odor at 0.82, for the medium signal odor at 0.78, and for the low signal odor at 0.77 (Figure 2). There was not a significant difference in VI across baseline sessions overall or for any trial type. There were no significant effects of trial type or trial block on VI. There were also no significant interactions between trial block and trial type on VI.

Figure 2.

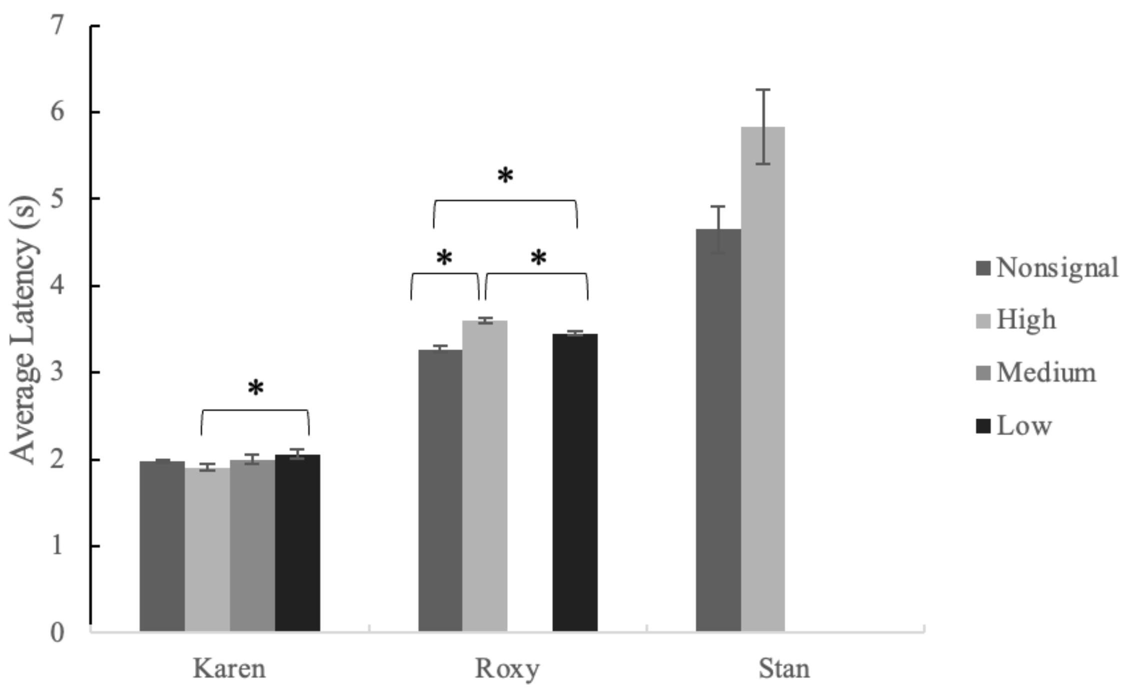
Vigilance Index for Baseline Performance of Each Odor Level by Dog



The average trial latency was 1.98-s for nonsignal trials, 1.91-s for the high signal odor, 2.00-s for the medium signal odor, and 2.06-s for the low signal odor (Figure 3). The difference in latency between high signal odor trials and low signal odor trials was significant (p = .031; ±0.13, 95% C.I.) There were no other significant differences in latencies between trial types. There was no effect of trial block on latency and the interactions between trial block and trial type were not significant.

Figure 3

Baseline Average Latency by Trial Type for Each Dog



Roxy

Roxy's baseline performance stabilized at an average of 83% for nonsignal trials, 100% for the high signal odor, and 64% for the low signal odor with no errors of omission. Overall VI for baseline was 0.64, with VI for the high signal odor at 0.85 and VI for the low signal odor at

0.46 (see Figure 2). There was not a significant difference in VI across baseline sessions overall or for any trial type. The difference in VI for high and low signal odor trials was significant (p = .0016; ± 0.16, 95% C.I.). There was no effect of trial block on VI, nor were there any interactions between trial block and trial type on VI.

The average trial latency was 3.27-s for nonsignal trials, 3.60-s for high signal odor trials, and 3.45-s for low signal odor trials. The difference in latency between nonsignal trials and high signal odor trials was significant ($p < .01$; ±0.085, 95% C.I.), as well as the difference between nonsignal trials and low signal odor trials (p = .003; ±0.09, 95% C.I.) (see Figure 3). The difference in latency between high signal odor trials and low signal odor trials was also significant (p = .013; ±0.087, 95% C.I.). There was no effect of trial block on latency and the interaction between trial block and trial type was not significant.

Stan

Stan's baseline performance was 97% for nonsignal trials and 94% for signal trials with no errors of omission. Stan's baseline VI was 0.86 (see Figure 2). There was no effect of trial block on VI. The average trial latency was 4.65-s for nonsignal trials and 5.83-s for signal trials (see Figure 3). There was no effect of trial block or trial type on average latency and the interaction between trial block and trial type was not significant.

Discussion

The purpose of this experiment was to train the signal versus nonsignal trial discrimination and to establish baseline levels of detection performance for odors of differing levels of intensity. Dogs were able to effectively learn the discrimination task and performed the task with overall VI values ranging from 0.64-0.86, indicating relatively high levels of performance. Of the two dogs tested with differing odor intensity levels, one dog, Karen, exhibited no difference in VI across odor levels, while the other dog, Roxy, had a significantly higher VI for high signal odor trials compared to low signal odor trials. This difference in performance may be due to individual dog factors but is more likely due to differences in training. Karen received more experimenter assistance on the low signal odor trials throughout initial training which may have artificially inflated her performance for lower odor intensity levels. On the other hand, when the procedure was modified to achieve greater variability across odor intensity levels, Roxy only received experimenter assistance on the first occurrence of the low signal odor to prevent this artificial inflation of performance.

Based on the previously established literature on sustained attention task performance, it was hypothesized that performance would either decrease across trial blocks (resource depletion theory; mindlessness theory) or would fluctuate (resource-control theory; opportunity cost model). Neither of these patterns of performance were observed. There were no significant effects of trial block on VI observed for any dog, meaning dogs maintained performance levels across the duration of the task. Additionally, misses tended to be sporadic rather than clustered as would be expected with fluctuating performance. Together, these findings suggest that a 160-trial session (approximately 70-mins in duration) was not sufficient to diminish attentional resources in this condition and influence sustained attention processes.

Average response latency was largely dog-dependent, with average latencies ranging from 1.91-s to 5.83-s. There were also no consistent relationships between latencies for each trial type. Karen demonstrated a significantly higher latency for low signal odor trials compared to high signal odor trials, while Roxy demonstrated a significantly higher latency for high signal odor trials compared to low signal odor trials. These results may be indicative of a speed-accuracy tradeoff reflective of the amount of attention paid to the stimulus. Karen had a slower average latency and higher VI for low signal odor trials compared to Roxy, who demonstrated a faster average latency and a lower VI for low signal odor trials, suggesting that perhaps Karen was more attentive to the odor presentation site and thus more successful.

Experiment 2

A number of factors have been shown to negatively impact sustained attention task performance, including: task duration, signal probability, motivation, and background noise (Dember & Warm, 1979; Hancock, 2013; McGaughy & Sarter, 1995). The purpose of Experiment 2 was to evaluate these factors on dogs' performance. This was tested by extending the length of testing sessions, reducing signal probability, withholding reward for a subset of trials, and increasing competing olfactory information within the testing room.

Method

Subjects

The subject were the same three dogs from Experiment 1.

Apparatus and Stimuli

The testing apparatus and stimuli were the same as those described in Experiment 1. For the background noise test four essential oil diffusers (YoungLiving Dewdrop Diffuser) were used containing butter rum, champagne, marshmallow, and peanut butter oils (Great American Spice Company).

Procedure

Sustained Attention Test

Dogs' ability to perform a sustained attention task was evaluated by giving dogs one session of extended length. The test session was organized in the same manner as Experiment 1 sessions, however the test session was double the number of trials used for the baseline sessions

(324 for Karen, 320 for Roxy and Stan), made up of equal trials of signal and nonsignal event trials. Signal trials were made up of equal trials of each odor intensity used for the dog's baseline sessions in Experiment 1.

Vigilance Test

In order to assess whether dogs demonstrate the vigilance decrement phenomenon, dogs received one test session that was double the number of trials of the dog's baseline session that had a signal probability of 10%, such that there were only 30 signal trials. Signal events in this test session were made up of the highest odor signal used in each dog's baseline sessions (with the exception of Karen, who's signal events were made up of the medium intensity odor used in her baseline sessions). Between each trial there was a 20-s ITI. Dogs received a food reward accompanied by a tone for all correct responses and a verbal "No" for incorrect responses. Dogs were retrained to baseline levels before beginning the next test condition (3, 1, and 1 session respectively for Karen, Roxy, and Stan).

Motivation Test

To evaluate the effect of motivation on continued sustained attention task performance, dogs were given an extended test session identical in structure to the vigilance test, however, in this session dogs only received a food reward accompanied by a tone for signal events. For correct responses on nonsignal event trials, dogs received only the tone. All incorrect responses resulted in a verbal "No". Signal events in this test session were made up of the highest odor signal used in each dog's baseline sessions (with the exception of Karen, who's signal events were made up of the medium intensity odor used in her baseline sessions). Between each trial there was a 20-s ITI. For this session, a termination criterion was implemented such that three consecutive errors of omission resulted in termination of the session. Dogs were retrained to baseline levels before beginning the test condition (2, 1, and 1 session respectively for Karen, Roxy, and Stan).

Background Noise Test

Dogs were tested on a sustained attention test in the presence of increased background noise. Test sessions were structured identically to baseline sessions, however signal discriminability was reduced by saturating the testing room with other odors. An essential oil diffuser containing champagne oil was turned on 30-minutes prior to testing. When testing began, the diffuser containing champagne was turned off and diffusers containing butter rum, peanut butter, and marshmallow oils were allowed to diffuse in 15-minute increments following that order for the duration of the test. Dogs received three test sessions within this condition.

Data Analysis

Data analysis occurred in the same manner as Experiment 1. All dependent measures were the same, however, the makeup of trial blocks in Experiment 2 differed slightly. For the sustained attention test session, there were eight, 40-trial trial blocks made up of even numbers of signal and nonsignal trials. For the vigilance and motivation test sessions, there were six, 54-trial trial blocks with only five signal trials per trial block. For the background noise session, there were three sessions with four, 40-trial trial blocks made up of even numbers of signal and nonsignal trials.

Within session analyses occurred in the same manner as Experiment 1. In order to compare performance on test sessions (collapsed across sessions for the background noise test) in Experiment 2 with baseline performance, a general linear model was used to compare overall VI across tests, as well as VI for each trial type for the sustained attention and background noise tests. Additionally, for the background noise test a general linear model was used to evaluate the effect of session number and trial type on VI.

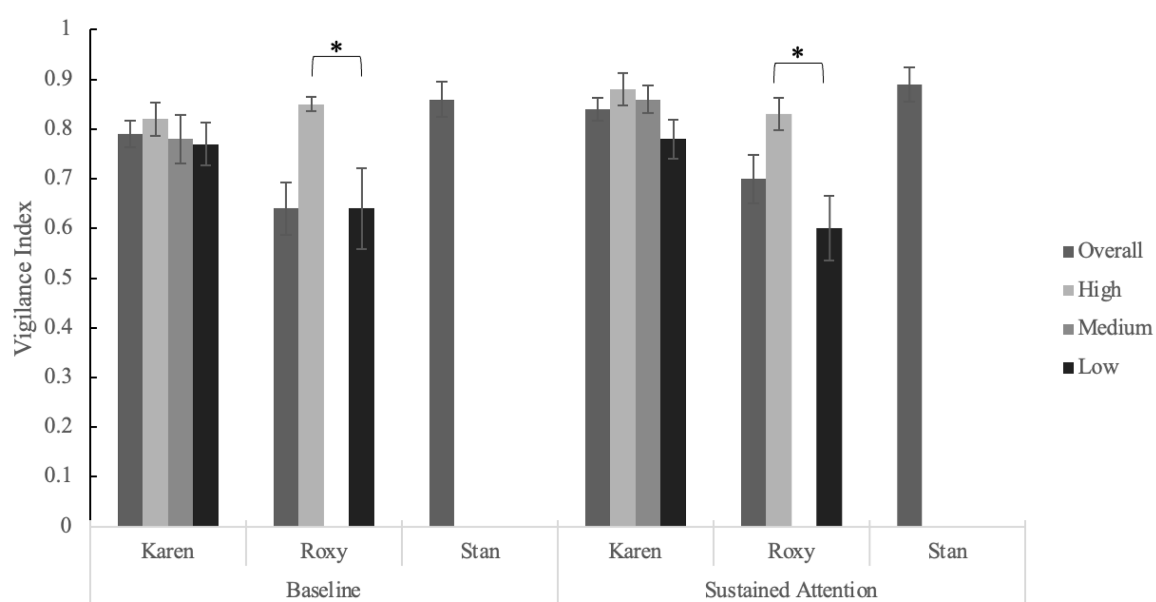
Results

Sustained Attention Test

Karen. Karen performed at 90% accuracy for nonsignal trials, 98% for high signal odor trials, 96% for medium signal odor trials, and 89% for low signal odor trials. There were no errors of omission. Overall VI for this session was 0.84, with VI for high signal odor trials at 0.88, VI for medium signal trials at 0.86, and VI for low signal trials at 0.78. There were no significant relationships between trial type or trial block on VI. There were no significant differences in VI for this test session compared to baseline for any trial type (Figure 4).

Figure 4

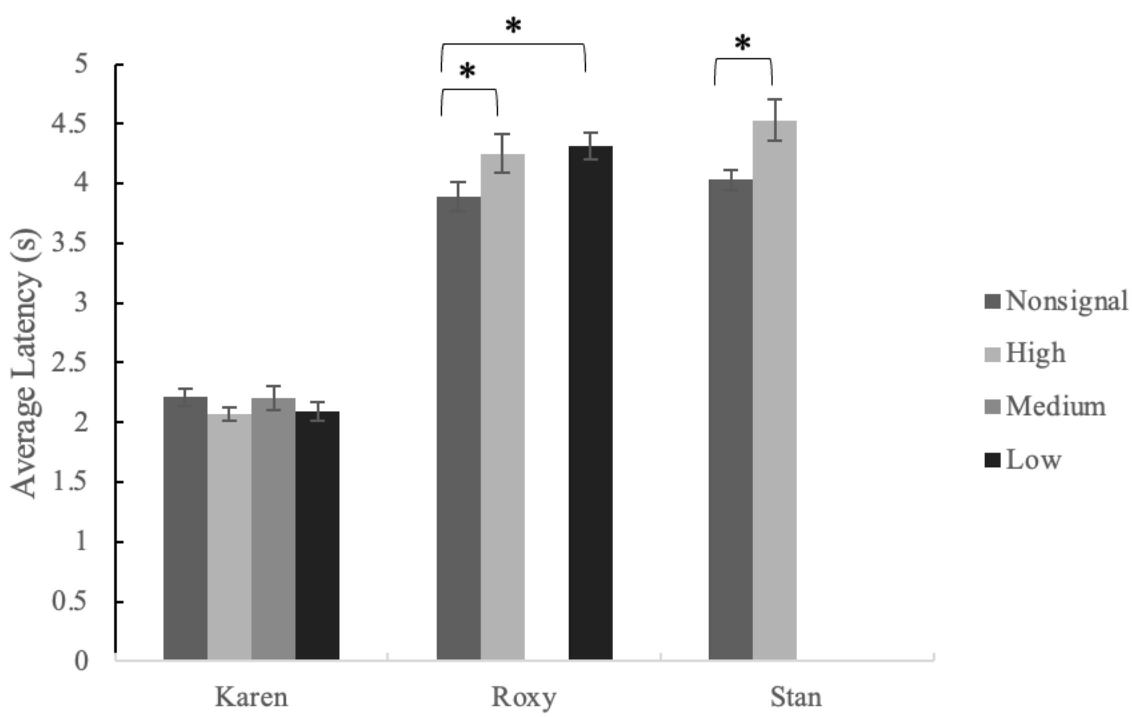
VI for Baseline Versus the Sustained Attention Test for Each Trial Type Across Dogs



The average trial latency was 2.21-s for nonsignal trials, 2.07-s for high signal odor trials, 2.20-s for medium signal odor trials, and 2.09-s for low signal odor trials (Figure 5). There was a significant effect of trial block on latency, with latency increasing 0.037-s with each trial block (p = .023; ±0.20, 95% C.I.). There was no effect of trial type on latency and the interactions between trial block and trial type were not significant.

Figure 5

Latency for Each Trial Type Across Dogs for the Sustained Attention Test



Roxy. Roxy performed at 82% accuracy for nonsignal trials, 99% accuracy for high signal odor trials, and 78% accuracy for low signal odor trials. There was one error of omission, a high signal odor trial in trial block 2. Overall VI for this session was 0.7, with VI for high signal odor trials at 0.83 and VI for low signal odor trials at 0.6. The difference between VI for high signal odor trials and low signal trials was significantly different (p = .0012; ±0.12, 95%

C.I.). There was no effect of trial block on VI and the interaction between trial block and trial type was not significant. The difference in VI for this test session compared to baseline VI was not significant (see Figure 4).

The average trial latency was 3.89-s for nonsignal trials, 4.25-s for high signal odor trials, and 4.31-s for low signal odor trials. Interactions between trial block and trial type were not significant. The difference in latency was significant between nonsignal trials and both high signal odor trials ($p = .04$; ±0.31, 95% C.I.) and low signal odors ($p = .02$; ±0.32, 95% C.I.) (see Figure 5). There was no significant difference between latencies for high and low signal odors.

Stan. Stan performed at 98% accuracy for nonsignal trials and 90% accuracy for signal trials with no errors of omission. Vigilance index was 0.89. The effect of trial block on VI was not significant. Vigilance index for this test session was not significantly different from baseline VI (see Figure 4).

The average trial latency was 4.03-s for nonsignal trials and 4.53-s for signal trials. The difference in latency between trial types was significant ($p = .012$; ±0.37, 95% C.I.) (see figure 5). There was no effect of trial block on latency, nor a significant interaction between trial block and trial type on latency.

Vigilance Test

Karen. Karen performed at 89% accuracy for nonsignal trials and 100% for signal trials with no errors of omission. Vigilance index for this test session was 0.90. There was not a significant difference in VI compared to baseline (Figure 6). There was a significant effect of trial block on VI, with VI increasing 0.040 across each trial block ($p = .0044$; ±0.014, 95% C.I.) (Figure 7). The average trial latency was 2.11-s for nonsignal trials and 2.07-s for signal trials. There were no significant effects of trial type or trial block on latency (Figure 8).

Figure 6

VI for Baseline Versus the Vigilance Test Across Dogs

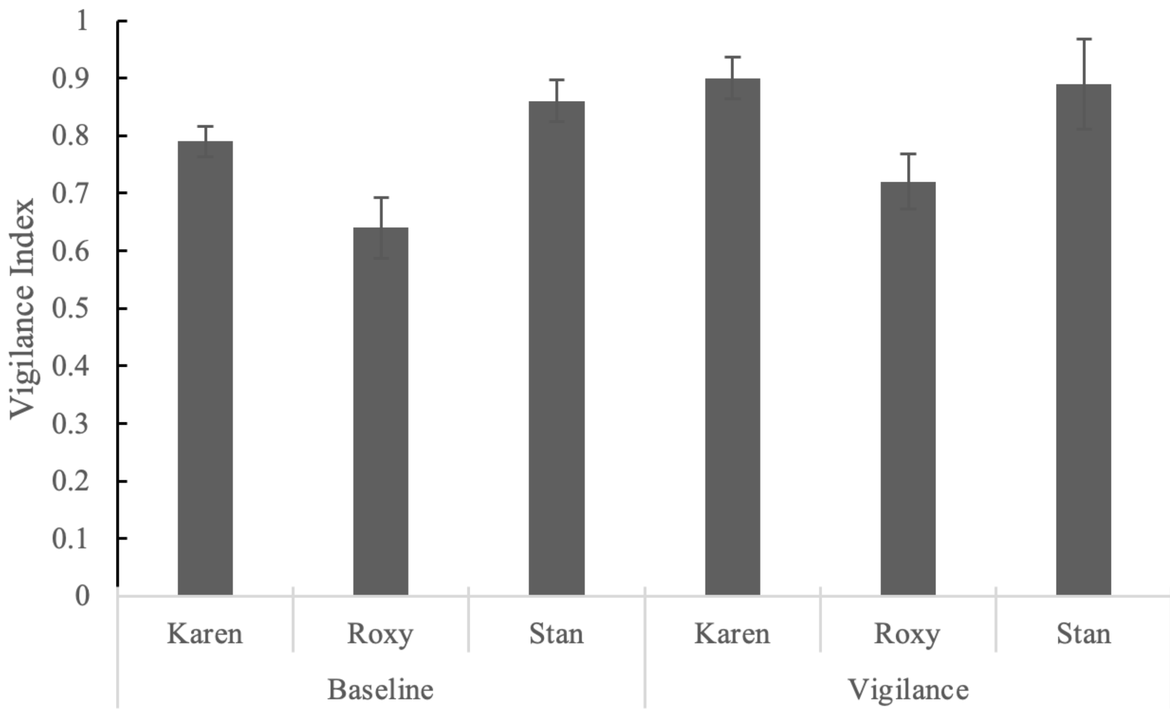


Figure 7

Karen's Increasing VI Across Vigilance Test Trial Blocks

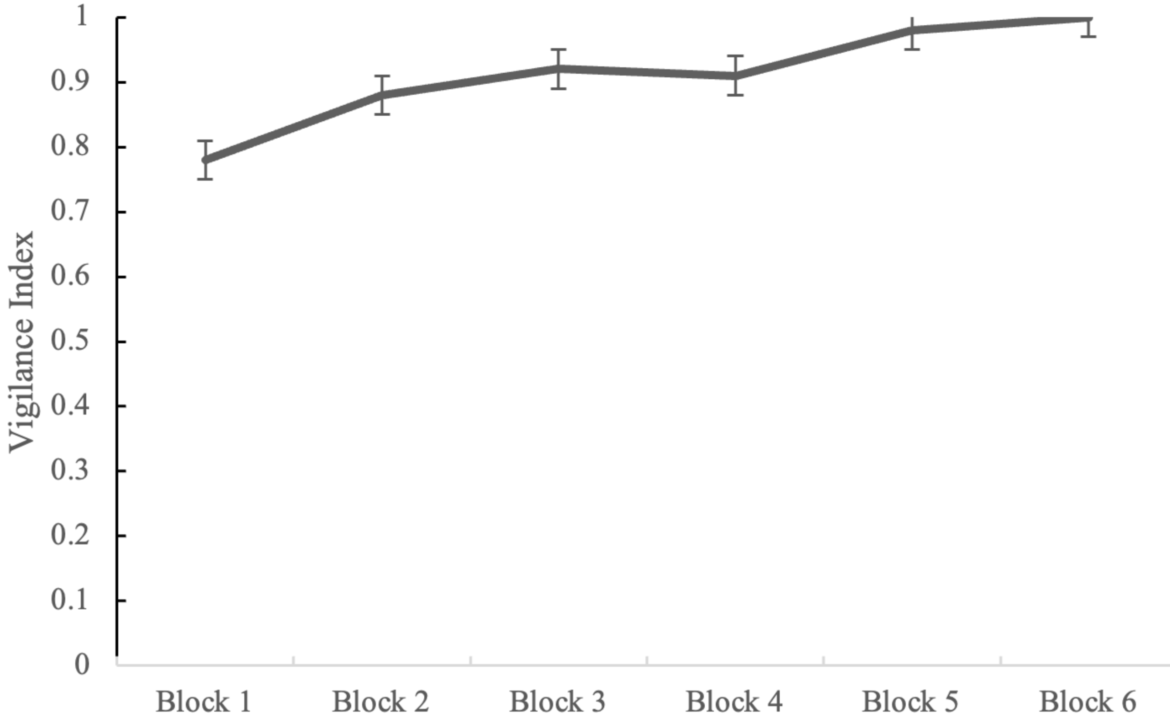
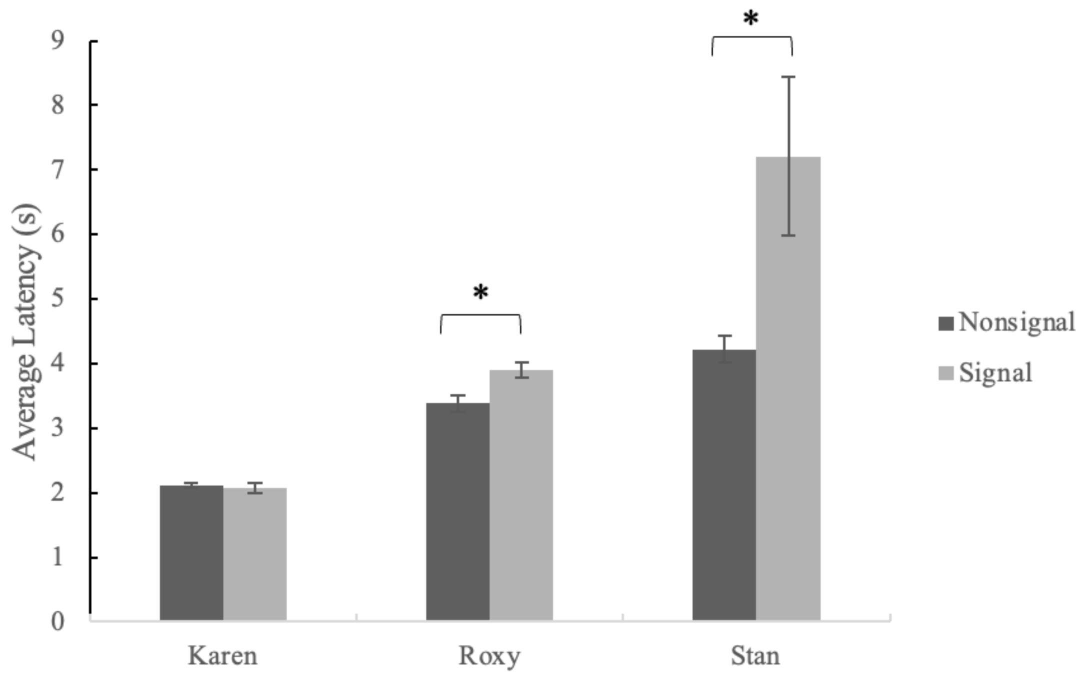


Figure 8

Latency for Each Trial Type Across Dogs for the Vigilance Test

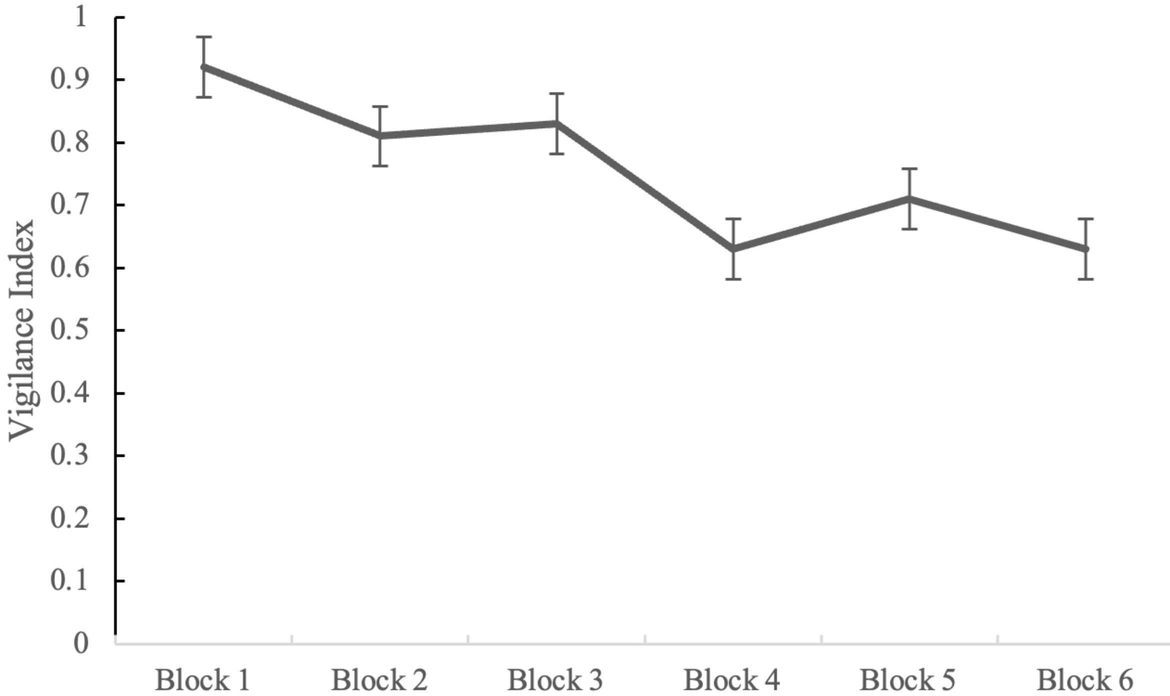


Roxy. Roxy performed at 98% accuracy for nonsignal trials and 67% for signal trials. There were five errors of omission, all of which were nonsignal trials (one in trial block 5 and four in trial block 6). Vigilance index for this test session was 0.72. The difference in VI for this test session compared to baseline was not significant (see Figure 6).There was a significant effect of trial block on VI, with VI decreasing 0.056 across each trial block (p = .016; ±0.026, 95% C.I.) (Figure 9).

The average trial latency was 3.38-s for nonsignal trials and 3.9-s for signal trials (see Figure 8). The difference in latency between nonsignal and signal trials was significant (p = .015; ±0.34, 95% C.I.). The interaction between trial block and trial type was not significant, nor was the effect of trial block on latency.

Figure 9

Roxy's Decreasing VI Across Vigilance Test Trial Blocks



Stan. Stan performed at 99% accuracy for nonsignal trials and 89% accuracy for signal trials. There were 13 errors of omission, made up of 11 signal trials and 2 nonsignal trials (Table 5). Vigilance index for this session was 0.89. There was not a significant effect of trial block on VI. The difference in VI for this session compared to baseline was not significant (see Figure 6).

Table 5

Errors of Omission by Trial Block for Stan's Vigilance Test

Trial Block	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
Errors of Omission	0 signal 0 nonsignal	0 signal 0 nonsignal	0 signal 0 nonsignal	3 signal 1 nonsignal	3 signal 0 nonsignal	5 signal 1 nonsignal

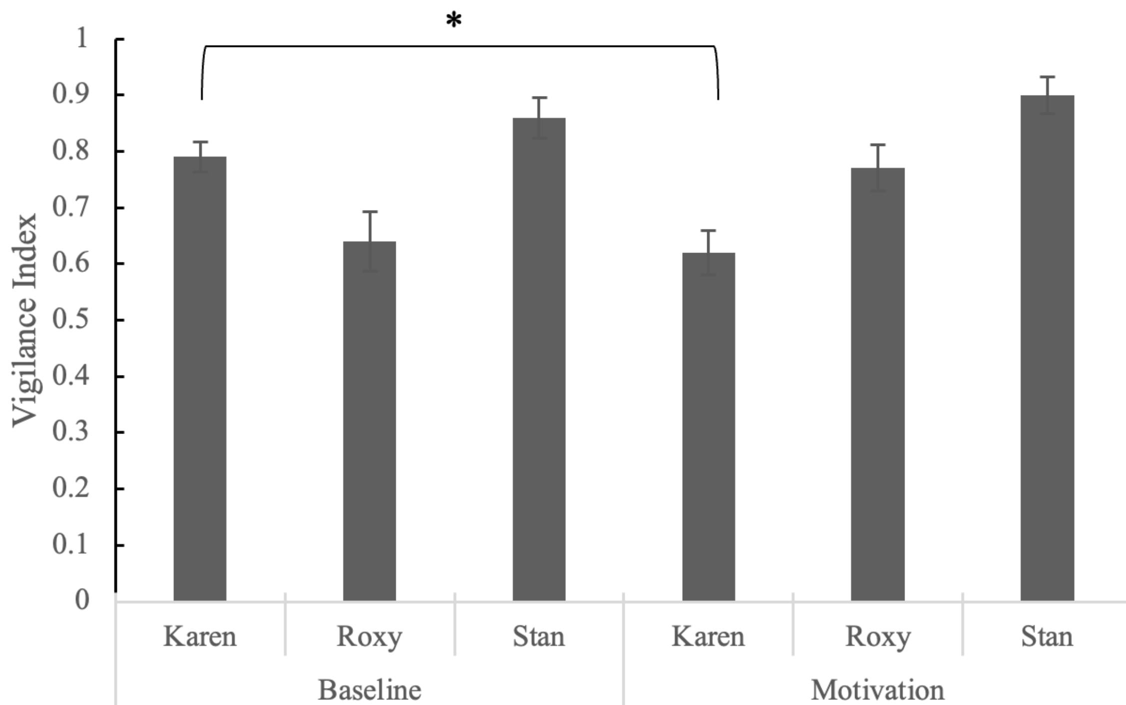
The average trial latency was 4.22-s for nonsignal trials and 7.21-s for signal trials (see Figure 8). The interaction between trial block and trial type on latency was not significant. There was a main effect of trial block, such that latency increased 0.73-s across each trial block (p = .04; ±0.59, 95% C.I.). Additionally, the difference in latency between signal and nonsignal trials was significant (p = .02; ±0.59, 95% C.I.).

Motivation Test

Karen. Karen completed 163 out of 320 trials in the motivation test before meeting the termination criterion. Only completed trial blocks were included in analyses. Karen performed at 40% accuracy for nonsignal trials and 100% accuracy for signal trials. There were five errors of omission. All errors of omission were nonsignal trials, with one omission in both trial blocks 2 and 3 and three omissions in trial block 4. Vigilance index for the motivation test was 0.62. There was no effect of trial block on VI. There was a significant difference in VI for this test compared to baseline, with VI in this session 0.16 lower than baseline (p = .0048; ±0.12, 95% C.I.) (Figure 10).

Figure 10

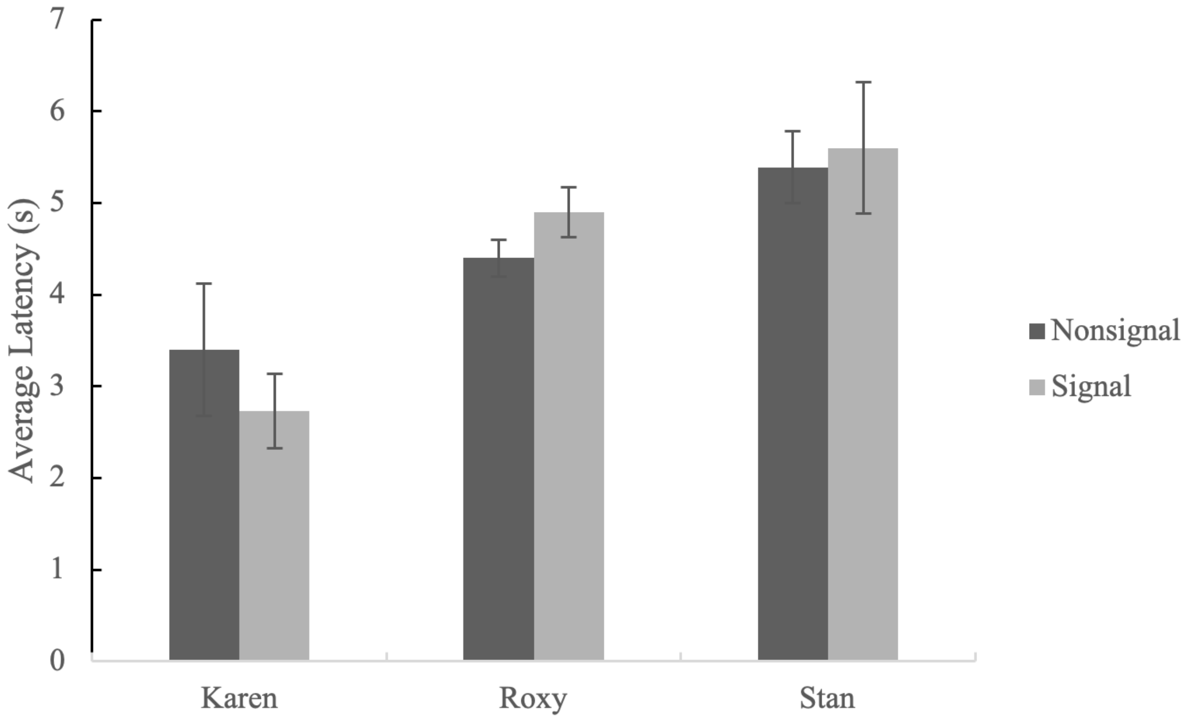
VI for Baseline Versus the Motivation Test Across Dogs



The average trial latency was 3.40-s for nonsignal trials and 2.73-s for signal trials (Figure 11). There was a significant effect of trial block on latency, with latency increasing 0.96-s across each trial block (p = .014; ±0.36, 95% CI). The difference in latency between trial types was not significant. The interaction between trial block and trial type was also not significant.

Figure 11

Latency for Each Trial Type Across Dogs for the Motivation Test



Roxy. Roxy completed 320 out of 320 trials in the motivation test. She performed at 77% accuracy for nonsignal trials and 100% accuracy for signal trials. There were six errors of omission. All errors of omission occurred on nonsignal trials, with two omissions occurring in trial block 2 and four omissions occurring in trial block 3. Vigilance index for the motivation test was 0.77. There was no effect of trial block on VI. There was not a significant difference in VI for this test compared to baseline (see Figure 10).

The average trial latency was 4.40-s for nonsignal trials and 4.90-s for signal trials (see Figure 11). There was no effect of trial type or trial block on latency. The interaction between trial type and trial block was also not significant.

Stan. Stan completed 218 out of 320 trials in the motivation test before meeting the termination criterion. Only completed trial blocks were included in analyses. Stan performed at

89% accuracy for nonsignal trials and 100% for signal trials. There were 13 errors of omission, made up of one signal trial and 12 nonsignal trials (Table 6). Vigilance index for the motivation test was 0.90. There was no effect of trial block on VI. There was not a significant difference in VI for this test compared to baseline (see Figure 10).

Table 6

Errors of Omission by Trial Block for Stan's Motivation Test

Trial Block	Block 1	Block 2	Block 3	Block 4	Block 5
Errors of Omission	0 signal 2 nonsignal	0 signal 2 nonsignal	0 signal 2 nonsignal	0 signal 3 nonsignal	1 signal 3 nonsignal

The average trial latency was 5.39-s for nonsignal trials and 5.6-s for signal trials (see Figure 11). There was a significant effect of trial block, with latency increasing 0.78-s across each trial block (p = .01; ±0.39, 95% C.I.). There was no effect of trial type on latency and the interaction between trial type and trial block was not significant.

Background Noise Test

Karen. Karen performed at 91% accuracy for nonsignal trials, 91% for the high signal odor, 96% for the medium signal odor, and 94% for the low signal odor. There was a significant improvement in VI across the three days of background noise testing such that VI increased by 0.066 each day. There were no significant interactions between day and trial type, suggesting that this increase in VI was not driven by any one trial type. There were no errors of omission. The overall VI for the background noise test was 0.85, with VI for the high signal odor at 0.83, VI for the medium signal odor at 0.88, and VI for the low signal odor at 0.85. There was not a significant difference in VI for the background noise test compared to baseline VI (Figure 12).

There was a significant interaction between trial block and trial type on VI, with VI for low signal odor trials greater than VI for high signal odor trials in earlier trial blocks, but VI for high signal odor trials increasing and surpassing VI for low signal odor trials in later trial blocks (p = .046; ±.042, 95% C.I.) (Figure 13). However, main effects of trial block and trial type did not reach significance.

Figure 12

VI for Baseline Versus the Background Noise Test (BGN) for Each Trial Type Across Dogs

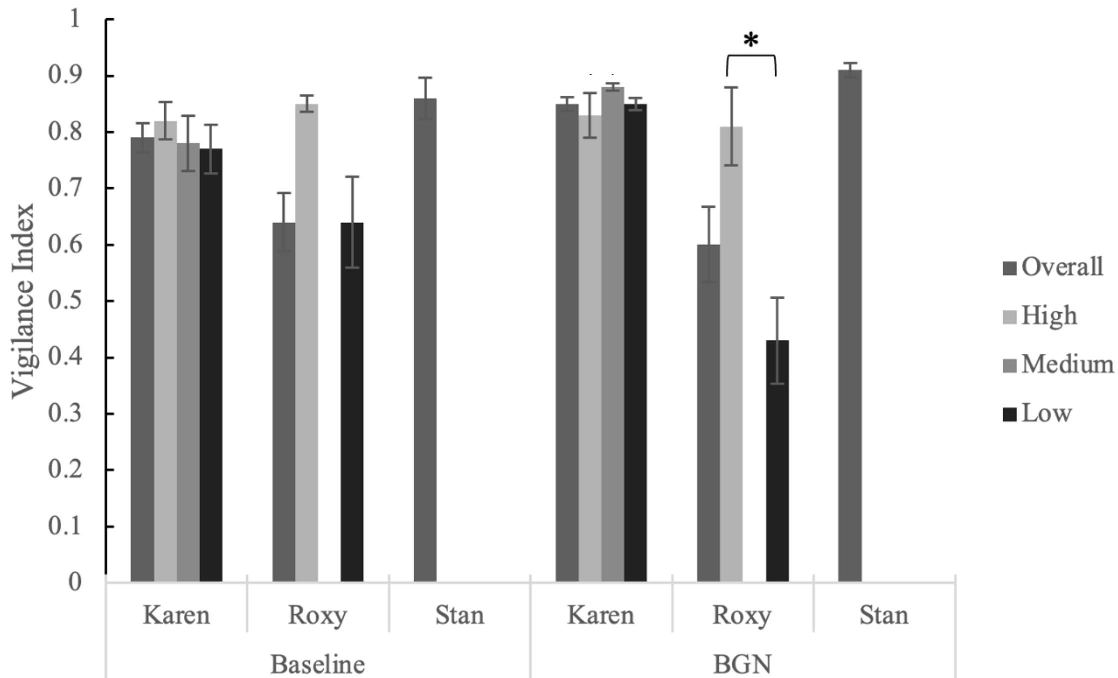
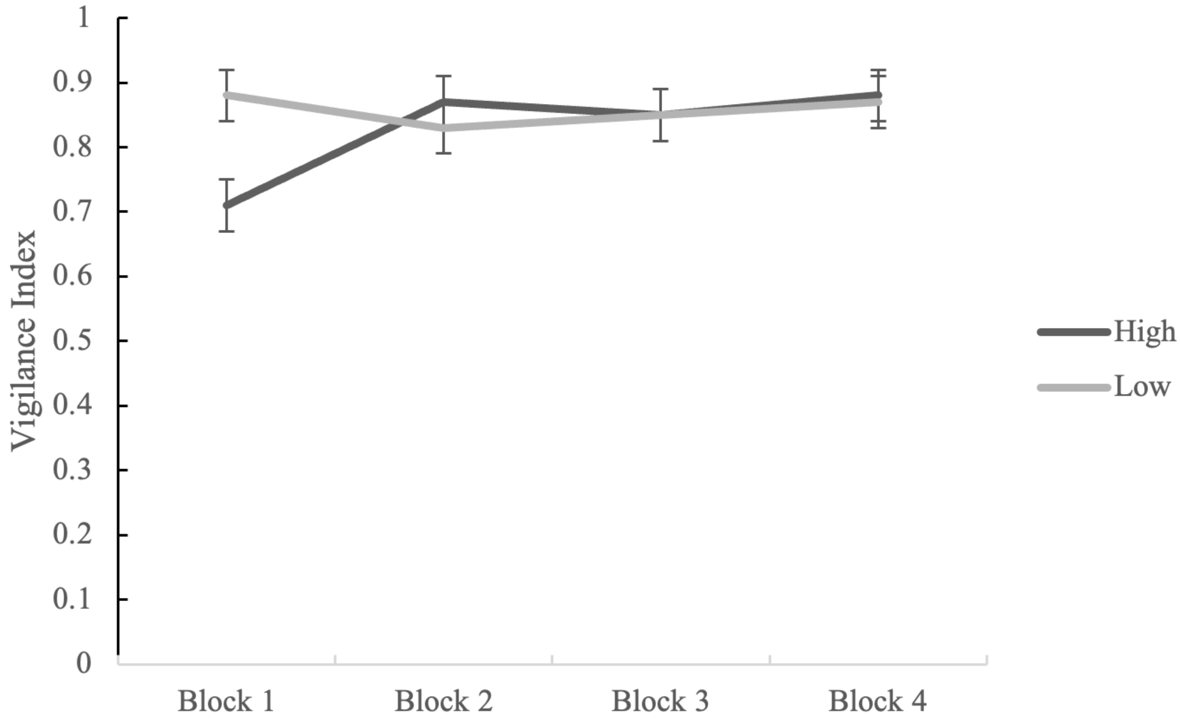


Figure 13

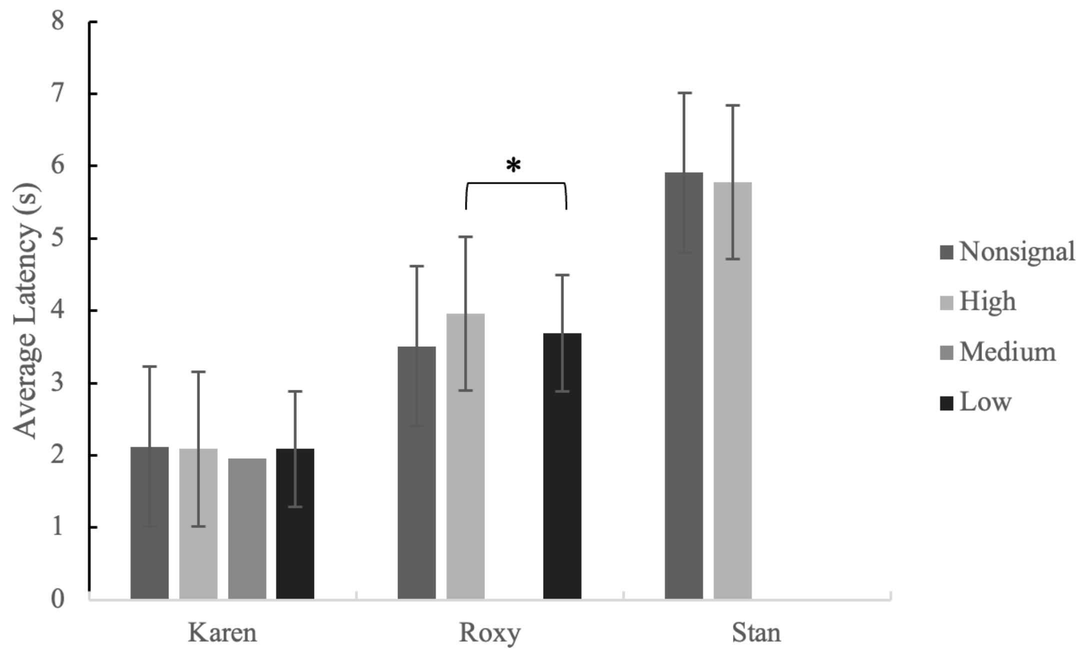
Interaction Between Karen's VI for High Signal Odor and Low Signal Odors for the Background Noise Test



The average trial latency was 2.12-s for nonsignal trials, 2.09-s for the high signal odor, 1.96-s for the medium signal odor, and 2.09-s for the low signal odor (Figure 14). There was no effect of trial type or trial block on latency. The interactions between trial type and trial block were also not significant.

Figure 14

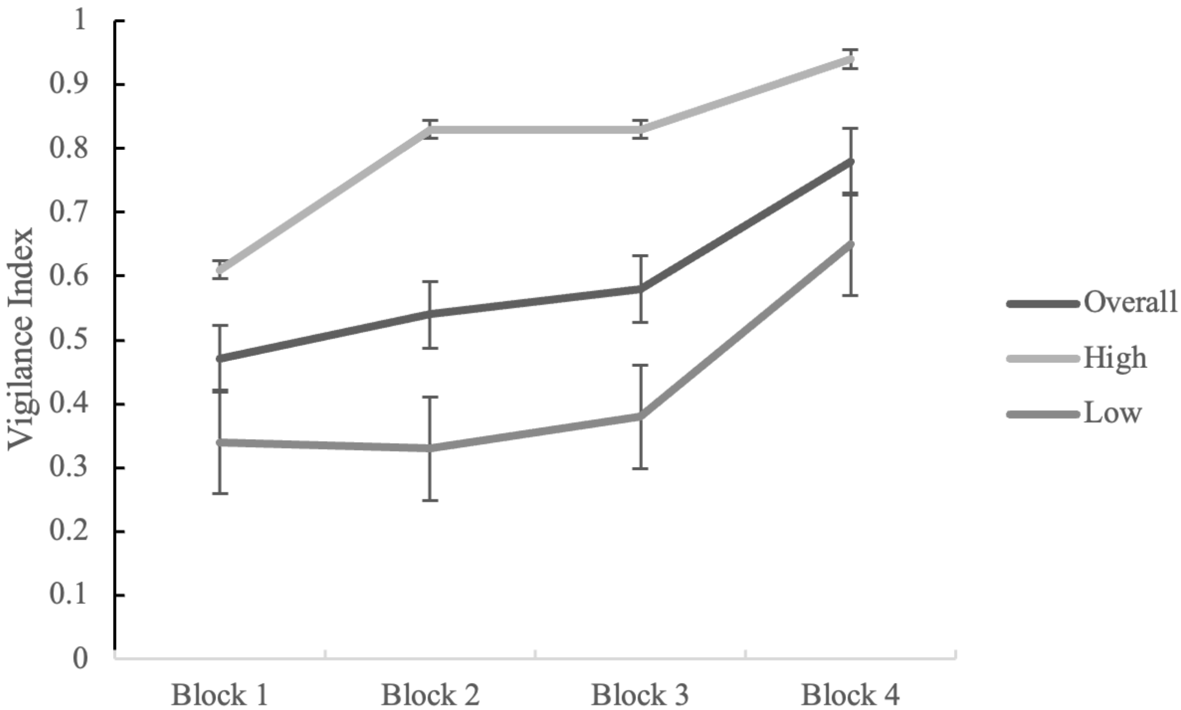
Latency for Each Trial Type Across Dogs for the Background Noise Test



Roxy. Roxy performed at 82% accuracy for nonsignal trials, 97% for high signal odor trials, and 58% for low signal odor trials. There was not a significant difference in VI across testing days. There was one error of omission – a nonsignal trial in trial block 3. Overall VI was 0.6, with a high signal odor trial VI of 0.81 and low signal odor VI of 0.43. There was not a significant difference in VI for the background noise test compared to baseline VI (see Figure 12). The difference in VI between high signal odor trials and low signal odor trials was significant (p <.01; ±.09, 95% C.I.). There was also a significant effect of trial block on VI, with VI increasing 0.098 across each trial block (p = .00045; ±0.028, 95% C.I.) (Figure 13).

Figure 15

Roxy's Increasing VI Across Trial Blocks for the Background Noise Test



The average trial latency was 3.51-s for nonsignal trials, 3.96-s for the high signal odor, and 3.69-s for the low signal odor (see Figure 14). The difference in latency between high signal odor trials and nonsignal trials was significant (p = .011; ±0.27, 95% C.I.). There were no other trial type effects. The effect of trial block on latency was not significant, nor was the interaction between trial type and trial block.

Stan. Stan performed at 97% accuracy for nonsignal trials and 94% accuracy for signal trials. There was not a significant difference in VI across testing days. There were 10 errors of omission, made up of seven signal trials and three nonsignal trials (Table 7). Vigilance index was 0.91. There was no effect of trial block on VI. There was not a significant difference in VI for this condition compared to baseline VI (see Figure 12).

Table 7

Errors of Omission by Trial Block for Stan's Background Noise Test

Trial Block	Block 1	Block 2	Block 3	Block 4
Errors of Omission	2 signal 0 nonsignal	2 signal 1 nonsignal	0 signal 1 nonsignal	3 signal 1 nonsignal

The average trial latency was 5.91-s for nonsignal trials and 5.78-s of signal trials (see Figure 14). There was a significant effect of trial block on latency, with latency increasing 0.43-s across each trial block (p = .002; ±0.15, 95% C.I.). There was no effect of trial type on latency. The interaction between trial type and trial block was also not significant.

Discussion

Sustained Attention Test

The purpose of the sustained attention test was to evaluate the effect of extended test length on VI. This was tested by giving dogs a session that was double the number of trials of a baseline session. Dogs were overwhelmingly able to maintain baseline VI levels in the testing session. No dog's VI for this test differed significantly from baseline. Additionally, no dog demonstrated an effect of trial block on VI, suggesting they were able to maintain baseline levels of performance across the duration of the test.

There were several significant effects of latency, however, these were largely dog-dependent. Karen demonstrated an increased response latency across trial blocks, perhaps due to mental or physical fatigue, however no other dog demonstrated this trend. Stan and Roxy both demonstrated higher latency for signal trials than nonsignal trials. This effect was consistent with baseline trial latencies for Roxy, suggesting that her performance of the nonsignal trial response may generally have been faster than her performance of the signal trial response. Stan did not demonstrate this effect in his baseline session.

For the two dogs that had differing odor intensity levels, the effect of trial type on VI was dog-dependent. Karen did not demonstrate any effect of trial type on VI, matching baseline levels of performance for each trial type (signal odor intensities and nonsignal). On the other hand, Roxy had a significantly higher VI for the high intensity odor signal than the low intensity odor signal. This effect was consistent with baseline performance, in which VI for high intensity odor signals was also significantly greater than for low intensity odor signals.

In summary, there was no detrimental effect of extended session length on VI. Effects on latency and relationships between trial type and performance were largely dog-dependent.

Vigilance Test

The purpose of the vigilance test was to evaluate vigilance decrement in dogs. This was tested by extending session length and reducing signal probability to 10%. Dogs' performance on the vigilance test was variable. Karen demonstrated an increase in VI across trial blocks, Stan demonstrated no effect of trial block on VI, and Roxy demonstrated a decrease in VI across trial blocks. In all these instances, VI for the vigilance test did not differ significantly from baseline VI, suggesting that dogs were able to maintain vigilance levels despite the reduced signal probability.

Effects of latency were again dog-dependent. Karen demonstrated no changes in latency across the session or trial type differences in latency. Stan demonstrated an increase in average response latency across trial blocks and a significantly faster average latency for nonsignal trials compared to signal trials, consistent with his average latencies in the sustained attention test but not baseline. Roxy also demonstrated a significantly faster average latency for nonsignal trials compared to signal trials, consistent with both her baseline and sustained attention test latencies.

Overall, dogs were able to maintain baseline vigilance levels despite reduced signal probability and increased session length. One dog, Roxy, did display a decrease in VI across trial blocks, however her overall VI was still comparable to baseline, suggesting that the decrease in performance was not substantial. Taken together, it seems likely that olfactory signal detection performance for these dogs is quite resilient, neither this procedure nor the extended session length was not sufficient to induce vigilance decrement.

Motivation Test

The purpose of the motivation test was to examine the effect of extrinsic reward in maintaining signal detection performance under vigilance conditions (signal probability of 10% or less). In this test, dogs were only rewarded for signal trials, which comprised 30 trials out of 320. Two out of three dogs, Stan and Roxy, maintained baseline VI levels throughout the motivation test, providing further evidence as to the resilience of olfactory signal detection performance by these dogs. However, despite his high vigilance levels Stan still met the session-termination criterion of three consecutive errors of omission, ending his session at trial 218 out of 320. Roxy was able to complete the whole session. On the other hand, Karen’s VI for this session was significantly lower than her baseline VI and she met the session-termination criterion at trial 163. These results suggest that extrinsic motivation may affect individuals differently, with some dogs demonstrating greater dependence on external reward than others.

Latency effects in the motivation test were also dog-dependent. Karen and Stan both demonstrated an increase in average response latency across trial blocks, likely a result of reduced task-motivation. There were no latency effects observed for Roxy.

Overall, dogs were largely able to maintain baseline performance levels in the motivation test, suggesting that dogs are able to maintain performance on vigilance tasks in the absence of extrinsic motivation. Karen's VI for this session was significantly lower than her baseline VI, however, she performed at 100% accuracy for signal trials, suggesting that this reduction in VI was driven more by a response bias than an actual decline in vigilance.

Background Noise Test

The purpose of the background noise test was to investigate the effect of increased environmental noise (in the form of competing olfactory information) on VI. This was done by allowing essential oil diffusers to run throughout the test sessions. Dogs' performance was largely unaffected by the extraneous olfactory information. There were no significant differences in VI for this session compared to baseline for any dog.

There were several significant effects dependent on individual dogs in the background noise test. Karen demonstrated an increase in overall VI across days, suggesting that her ability to detect the signal odors in the presence of increased background odor improved across days with greater experience. She was the only dog to demonstrate a change in VI across testing days. Karen also demonstrated an interaction in VI for high and low signal odor intensities, with VI for low signal odor trials starting higher than VI for high signal odor trials, but with high signal odor VI eventually surpassing low signal odor VI in later trial blocks. Roxy demonstrated a higher VI for high signal odor trials than for low signal odor trials, with overall VI increasing across trial blocks.

Latency effects were also dog-dependent. Karen did not demonstrate any effects of latency. Stan's average trial latency increased across trial blocks, with no effect of trial. This result is consistent with his performance in both the motivation and vigilance tests, in which he also demonstrated increased latency across trial blocks, likely as a result of increased physical/cognitive fatigue. Roxy demonstrated a higher average response latency for signal trials compared to nonsignal trials, consistent with her performance in the vigilance, sustained attention, and baseline sessions, indicating that it likely took her generally longer to perform the signal trial response than the nonsignal trial response.

In summary, effects of background noise on performance were largely dog dependent. However, no dogs demonstrated a significant difference in VI for this test compared to baseline, suggesting that they were able to maintain baseline performance levels under conditions of extraneous olfactory noise.

General Discussion

The purpose of these experiments was to establish baseline levels of sustained attention task performance for a cohort of dogs and to evaluate conditions under which dogs' sustained attention task performance might be negatively impacted. In Experiment 1, dogs effectively learned an olfactory discrimination task for different levels of amyl acetate diluted in mineral oil compared to mineral oil only. In Experiment 2, dogs were overwhelmingly able to maintain baseline VI levels across all manipulations, including extended session length, reduced signal probability, reduced extrinsic motivation, and increased background noise. There was only one instance in which VI differed significantly from baseline: Karen's VI for the motivation session was significantly lower than her baseline VI.

There were no consistent patterns of performance across dogs for any test, suggesting that performance on these types of tests may largely be dependent on individual factors. For example, in the vigilance test Karen's VI increased across trial blocks while Roxy's decreased and Stan's remained stable. Supporting the role of individual factors on performance, there are some consistent within-subject effects across tests. Stan demonstrated increased latency across trial blocks on all tests except for baseline and sustained attention. This might be due to the increased physical demands of the extended testing sessions or due to increased cognitive demands as a result of reduced signal probability and increased background noise. Similarly, Roxy demonstrated greater average response latency for signal trials compared to nonsignal trials across all testing conditions except motivation, suggesting that the signal response likely took her longer to perform than the nonsignal response. Another possible explanation for differences in performance across dogs is the differing training experiences of each dog in Experiment 1. Karen and Stan both received greater levels of assistance on low signal odor trials during acquisition training, which may have facilitated higher overall VI levels for these dogs compared to Roxy. Additionally, the differences in testing parameters (e.g. different number of signal odors) make direct comparisons between dogs difficult.

These findings contradict typical sustained attention literature, which has demonstrated negative impacts on sustained attention task performance as a result of extended session length, reduced signal probability, and reduced signal discriminability (Dember & Warm, 1979; McGaughy & Sarter, 1995; Warm, Parasuraman, & Matthews, 2008). These findings are also discordant with previous investigations into the sustained attention capabilities of other animals, which have found animals to be subject to many of the same sustained attention task performance parameters as humans (rats: Bushnell, 1999; McGaughy & Sarter, 1995; jumping spiders: Melrose, Nelson, Dolev, & Helton, 2019). The high performance rates observed in this study prevent us from drawing any conclusions as to the cognitive mechanisms at play when vigilance decrement occurs and/or sustained attention fails. Based upon theories of sustained attention task performance, it was expected that task performance might degrade as a result of exhausted cognitive resources (resource depletion theory), boredom (mindlessness theory), a default bias for mind-wandering (resource-control theory), or finally, due to lack of task motivation (opportunity-cost model). Dogs' maintenance of high performance levels across all task manipulations preclude us from making any causal inferences regarding sustained attention failures in dogs.

These findings have important implications to the work performed by detection dogs. Detection dogs must often work under conditions of extended search duration, low target probability, and substantial competing sensory information. It has been demonstrated that detection dog performance may be negatively impacted by time on task and/or context (Gazit et al, 2005; Porritt et al., 2015). Further, more recent research has shown a decline in search behaviors by dogs engaged in a detection task as a result of reduced target frequency (Aviles-Rosa et al. 2023; Dechant et al. 2023). However, the present findings suggest that the olfactory detection task as performed by dogs is largely resilient to these conditions and that dogs are able to maintain vigilance for desired targets.

There are a few possible reasons for these discrepancies. It is possible that this inflated resilience to task-related factors known to impact performance may be due to the testing parameters used (e.g., a sterile laboratory environment versus a complex operational search environment). Further, it is possible that the extensive amount of training required to learn the detection task generated an expectation of rich-target density within the testing context. Hence, the training itself may have served as a protective factor during the reduced signal probability conditions. Finally, it should be noted that, with the exception of Karen's medium and low odor intensity levels, the odors used in this study were fairly intense (a concentration of 10^{-5} amyl acetate in mineral oil can be faintly detected by the human nose). In operational contexts, dogs likely encounter far less intense target odor levels and these odors are often containerized, further reducing their detectability. Steeper performance decrements would likely be observed in the absence of over-training and with less intense signal stimuli. Future research should further investigate the impact of these factors on dogs' sustained attention task performance in both operational and laboratory settings.

This study has two major limitations. Firstly, the small sample size used limits generalizability of these results and may account for discrepant results seen in other studies. Limited subject availability combined with the large amounts of training needed to learn the task prevented this study from including an adequate number of dogs to make generalizable conclusions. Future research should investigate the sustained attention abilities of dogs with a larger population. Secondly, it is difficult to interpret relationships between dependent variables in this study due to the differing test-structure make-up used for each dog. Unexpected difficulties encountered during training resulted in each dog included in this study having different testing parameters.

Conclusions

Dogs were able to learn an olfactory discrimination task for differing levels of amyl acetate diluted in mineral oil compared to mineral oil only. Performance across differing levels of odor intensity was consistently high. Manipulations of testing parameters known to negatively impact sustained attention and vigilance performance in other species were ineffective at producing deleterious effects on sustained attention task performance in dogs in this study. Differing methods of training and differing testing parameters used across dogs make comparisons of performance across dogs difficult. Additionally, inadequate sample size and inconsistent testing measures make generalization of these results to broader populations of dogs impossible. Future research should focus on development and standardization of training and testing methods to assess sustained attention capabilities in dogs. Future methods should minimize the effects of overtraining, while allowing for variability in performance across differing signal intensities by providing minimal experimenter assistance, as was done with Roxy.

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