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The Effect of Reward Type and Reward Preference on the Performance of Detection Dogs

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Abstract

Eight young labradors and spaniels of working strains at Fjellanger Detection Dog Academy in Os, Norway, were used in an alternating treatment design to assess the effect of reward type (toy or food) and reward preference on performance in detection work. A discrimination test was conducted to define the individual preferences, before search reliability, time efficiency and search pattern was evaluated in a multiple choice detection test in the laboratory. The dogs tended to work faster for their individually preferred reward type, but more false alerts and a less systematic search pattern was observed. Toy rewards produced a lower false alert rate and a more focused search pattern. The findings should be interpreted with caution, as they are limited to steady state performance of highly trained dogs selected for odour detection, willing to work hard for both reward types. Future studies with larger sample sizes are suggested to validate the results and to assess the effects of reward types and reward preference in earlier stages of training. This research should also be broadened to examine the effectiveness of additional exemplars of food and toy reinforcers, combined with and without social interaction like praise and tug-of-war, in detecting a variety of different odour targets. These findings add to general understanding about methods of enhancing performance of highly trained individuals as well as contributing practical knowledge applicable to work with dogs trained for substance detection.

Sammendrag

Åtte unge labradorer og spanieler fra working-linjer ved Fjellanger hundeskole i Os ble brukt i et forsøk med alternerende behandlinger for å undersøke effekten av belønningstype (leke eller godbit) og belønningspreferanse. Hundenes belønningspreferanse ble bestemt ved en diskrimineringstest, før pålitelighet i søket, tidseffektivitet og systematikk i søket ble undersøkt under søk på en flervalgskarusell i laboratoriet. Hundene tenderte til å jobbe fortere for den foretrukne belønningen, men flere feilmeldinger og mindre systematisk søk ble observert. Belønning med lek ga lavere feilmeldingsrate og mer fokusert søk.

Funnene bør tolkes med forsiktighet. De er gyldige for prestasjoner av allerede innlærte ferdigheter hos veltrente brukshunder som er selektert for spesialsøk og som er villige til å jobbe hardt for både leker og godbiter. Nye forsøk basert på et større utvalg anbefales for å validere resultatene og for å undersøke effekten av belønningstype og –preferanse under nyinnlæring. Fremtidig forskning bør også utvides til å undersøke effektiviteten av flere forskjellige godbit- og lekbelønninger, både i kombinasjon med - og uten sosial interaksjon, blant annet ros og drakamp, på deteksjon av flere ulike luktemner. Disse funnene øker den generelle forståelsen om treningsmetoder for å heve prestasjonene til veltrente hunder, og bidrar med praktisk kunnskap som kan brukes i arbeidet med spesialsøkhunder.

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1. Introduction

"A dog's performance of a certain behavior depends on the dog's motivational state and the behavior's reinforcement history" (Lindsay 2000). In order to train dogs efficiently, an important factor is to find out what motivates the dog, or in other words, choose an appropriate reward[1] that reinforces the behavior effectively and elicits the optimal level of arousal.

There are few studies on motivational systems in dogs. General types of motivations in mammals are involved in for example eating and drinking behavior, sexual behavior, thermoregulation, aggression, fear and play (Toates 1986). In canids, there might be specific motivational states involved with social, predatory behavior and play (Svartberg 2000).

"Motivation is the strength of the tendency to engage in behavior considering both internal and external factors" (Toates 1986). Konorski (1967) described two general motivational systems: a positive system that energizes behavior that leads to pleasurable events, for example eating, drinking and sex, and a negative system that invigorates behavior that minimizes contact with aversive stimuli. Motivational states are hypothetical constructs and hard to define precisely.

A functional description of a motivational state's effect on behavior has been done by Kandel (1995). The three functions are an activating, a goal-directing and an organizing function.
The activating function affects the animal's general arousal. The level of general arousal is a critical factor for any specifically motivated behavior (Moruzzi 1969). Arousal levels have an optimal range depending of the nature of the each task (Easterbrook 1959). Within this range, the subject is concentrated and focused. Arousal levels above this range leads to a decreased number of cues that can be utilized. Increasing arousal levels will first improve and then impair performance. The next of Kandel's (1995) functions is about goal-directing behavior. The motivational state affects the perception of environmental cues and directs behavior towards a goal (Toates 1986). For example, if a dog is motivated by hunger, it is more likely to perceive stimuli that predict food and less likely to respond to other stimuli, while a dog in a state motivated for chasing and hunting is more likely to perceive fast movements and sudden noises in the field (Svartberg 2000). Finally, Kandel's (1995) organizing function is about how single

[1] The informal word "reward" and the formal and precise word "reinforcer" are used interchangeably throughout the thesis.

behaviors are combined into a specific, goal-oriented sequence.

To identify and define specific motivational systems in dogs precisely is no straightforward task. Leyhausen (1973) found that predation and feeding behavior are controlled by different mechanisms in cats, and Gustavson (1987) found that this is the case even in dogs. According to Coppinger (2001), the canine predatory behaviors can be split into eight steps: orient, eye, stalk, chase, grab-bite, kill-bite, dissect and consume. The intensity of some parts of the predatory sequence have been hypertrophied, while other parts have been deleted by selective breeding(Coppinger 2001). For example spaniels and retrievers are bred to hunt and retrieve, but not to kill and dissect. This suggests that there might be different motivational subsystems for each part of the sequence.

Dogs do not only perform predatory behaviors while hunting prey. The predatory sequence is not always functionally motivated, but is often directed towards non-edible objects like toys. The reinforcing activity to the individual dog is to perform the hypertrophied motor pattern, which actually is play behavior. Eibl-Eibesfeldt (1975) claims that play behavior is controlled by a separate motivational system. In breeding programs, detection dogs are commonly selected for strong motivation for hunting and object-play (Bach 2004).

Operant (or instrumental) conditioning is the learning process when behavior is affected by its consequences. Reinforcement is the process by which behavior is strengthened, and might be the most important link between motivational states and operant conditioning. An effective reinforcer acts as a motivational incentive and activates a motivational system. With positive reinforcement, a behavior is followed by any stimulus event, and as a result, the frequency of the behavior increases in the future in similar situations. The stimulus event or consequence is called positive reinforcer (Cooper 2007).

Many attempts to explain what makes a reinforcer have been proposed. Thorndike (1911) defined a reinforcer as a stimulus that resulted in a satisfying state of affairs, and that an animal is willing to respond to in order to receive it (the law of effect). Watson (1913) criticized Thorndike for the mentalistic term “satisfaction” because it was impossible to evaluate. Hull

(1943) proposed that reduction of an animal's needs ("drive") acts as reinforcement. The drive-reduction theory fails to explain reinforcers that don't appear to satisfy biological needs, for example play or secondary reinforcers. An elegant and practical solution to this is to not consider reinforcers as stimuli, but rather as opportunities to engage in behavior (Premack 1959). The Premack principle proposes that a more probable behavior will reinforce a less probable behavior. In these terms, the toy or food it self is not the reinforcer, but for example the behavior to chase the toy or to eat the food acts as the reinforcer. Premack also argued that the properties of a reinforcer are relative and not absolute, for example, food deprivation making food more effective as a reinforcer.

"The strength of instrumental responding is influenced by the Pavlovian properties of the context in which the response is performed" (Pearce 2008). Classical (also respondent or Pavlovian) conditioning is the pairing of two stimuli. Through classical conditioning innate reflexes, including emotional arousal, are brought under the predictive control of originally neutral stimuli (Lindsay 2000). While operant behaviors are controlled by their consequences, respondent behavior is elicited and mostly not under voluntary control. Even though there is a sharp theoretical distinction between operant and classical conditioning, both classes of learning act simultaneously. The reinforcer does not only reinforce operant behavior, it also elicits emotional arousal. Positive reinforcement is associated with hope or satisfaction, while the omission of an expected positive reinforcer might elicit disappointment or frustration.

Animals need to adjust their behavior to environmental demands. The history of reinforcement in similar situations influences the animal's choice and is matched with the relative reinforcement value for each available choice. Animals are able to anticipate the reward they will receive for performing a certain behavior in the presence of a given stimulus (Rescorla 1991). "The cognitive construct of expectancy learning combines classical (relative predictability) and operant information (relative controllability) derived from experience" (Lindsay 2000). Accurate predictions and successful control confirms the expected outcome and strengthens the performance of the learned behavior.

The level of motivation affects behavior in two ways depending on the training level. The rate of learning (acquisition) is higher with greater magnitude of reinforcement. According to many studies (see Davey (1981)), the magnitude of reinforcement does not affect the performance when a steady-state (or asymptotic) level of the behavior is reached. However, just as many studies, for example Crespi (1942), have shown that differential performance of asymptotic behavior can be maintained over many sessions. When the behavior has been learned, motivational variables will affect the animal's response to stimuli and the behavior associated with it. In discrimination tasks, "increasing motivation can lead to an increase in number of errors" (Weiss 2008). When reinforcer values are contrasted closely in time, the differential effect of reinforcer magnitude is greater (Crespi 1942; Harzem 1975) than if one single reinforcer is used over a long period of time (Jensen 1973). Crespi (1942) found that a negative contrast in the amount of pellets lead to a decrease in running speed in rats, and opposite, positive contrast made the rats run faster.

In the studies mentioned above the shifts in reinforcement typically involved changes only in magnitude. Reward systems used in detection dog training typically involve food (Fischer-Tenhagen et al. 2011; Gazit & Terkel 2003; Hall et al. 2013), praise and/or toy reward (Jezierski et al. 2014; Lazarowski & Dorman 2014; Maejima et al. 2007; Schoon et al. 2014). According to Furton (2001) food is the most common reward used for bomb detection dogs and is one of the strongest reinforcers for labradors and springer spaniels. Fukuzawa and Hayashi (2013) compared different types of reinforcers in dogs. They found that food lead to shorter response time after the cue compared to stroking and praise, but this difference was only observed in the early stages of training. Pongrácz et al. (2013) compared food rewards of different values in social learning situations and found that the social context (i.e human pointing) overrides the effect of reinforcer quality.

A question that remains unanswered is which type of reinforcers are the most appropriate for training specific behaviors. Svartberg (2000) suggests to choose appropriate reinforcers for the behavior you train, to vary the type of reinforcer and to avoid reinforcers that elicit very high levels of arousal to prevent them from distracting the dog's attention from the behavior.

In this study I have compared the effect of toy and food reinforcers in a non-social context on the performance of detection dogs at Fjellanger Detection and Training Academy (FDTA) located in Os, Norway.

1.2 Research objective

My objective was to study the effect of two different reward types, toy and food, on the performance of a detection task. Given the that feeding behavior and play behavior are controlled by different motivational systems (Eibl-Eibesfeldt 1975), there might be differences in performance depending on reward preference, and there might be general effects of each reward type.

1.3 Research questions and predictions

1. Does the choice of reward affect detection reliability? What is the effect of the dogs' preferred and non-preferred reward?

2. Does the choice of reward affect search time efficiency? Is there any effect of the dogs' preferred and non-preferred reward?

3. Does the choice of reward affect the search pattern? What is the effect of the dogs' preferred and non-preferred reward?

I hypothesized that there would be differences in detection performance depending on preference for a toy or food reinforcer as well as general effects of each type of reinforcer. I predicted that the dog's preferred reward would give a higher hit rate and the most time efficient search. If the preferred reward was "very strong", it might lead to a higher false alert rate and a less systematic search pattern, and thus take longer for the dog to indicate the target scent. The same might be seen as a general effect of toy rewards that elicit high arousal, even if the toy isn't the preferred reward.

2. Materials and methods

2.1 Research subjects

Eight dogs at the FDTA were used in the study. The dogs were five field trial-bred (FT) labradors, two FT springer spaniels and one FT cocker spaniel aged between 16 and 21 months (table 1). All experiments in this study were conducted in January 2009.

Table 1. The dogs used in the study

Dog	Breed	Sex	Date of birth
Kill	Springer	M	May 21 2007
Fly	Springer	F	May 21 2007
Cosmo	Labrador	M	March 23 2007
Codex	Labrador	M	March 23 2007
Cora	Labrador	F	March 23 2007
Caso	Labrador	M	March 23 2007
Coffie	Labrador	F	March 23 2007
Pryor	Cocker	F	August 14 2007

2.2 Buildings

2.2.1 Kennels and housing

The dogs were kept in individual kennel boxes indoors (1,50x1,65 m) with daytime access to outdoor boxes (1,50x2,30 m). Indoors they had visual, auditory and olfactory contact with each other through the barred door to the hall way. The walls between kennel boxes were solid. In the outdoor boxes they had some tactile contact with each other through the wire mesh sections. The whole group of eight dogs was taken for an approximately one hour off leash walk in the forest every morning where they could enjoy free running and play with each other. They were given access to large paddocks (7x15m) for at least 2 hours every evening. The dogs were fed about 15g dry kibble per kg BW daily (Hill's Science Plan Puppy Chicken [Fjellanger Hundepensjonat, Os, NO], protein 27,8%, fat 19,6%). The dogs were fed at 8:00 am and 4:30 pm. The dogs had free access to fresh drinking water. The standard was higher than the prescribed Norwegian animal welfare law.

The labradors were born in the detection dog center, and the spaniels were bought at 8 weeks of age. All the puppies went through a socialization and environmental training program during their first 12 months. Socialization and environmental training was done every week by the trainees at the FDTA and included socialization with people of different genders and ages, and environmental training such as traveling by car, experiencing city environment, different buildings, surfaces etc.

2.2.2 Detection laboratory and equipment

All test were done in the indoor detection laboratory. The working area was a room sized 3,4x4 meters, with two-way mirror on the wall between the working area and the observers office. In one corner of the working area there was a screen with a small two-way mirror behind which the trainer stood during training and operates the secondary reinforcer tones.

The reinforcers used were a medium sized Kong rubber dog toy [Dogman, Hagan, NO], and 1 cm thick slices of sausage cut in half (brand Gilde [Nortura, Stavanger, NO], protein 18%, fat 10%). In the preference test, I used two target mats in contrasting colors. In the multiple-choice detection test, I used an iron carousel (diameter 125 cm) with twelve arms radiating from a central hub. Each arm contained a holder that carried a disposable aluminum container (diameter 28 cm, height 70 cm) filled with pure sand (figure 1).

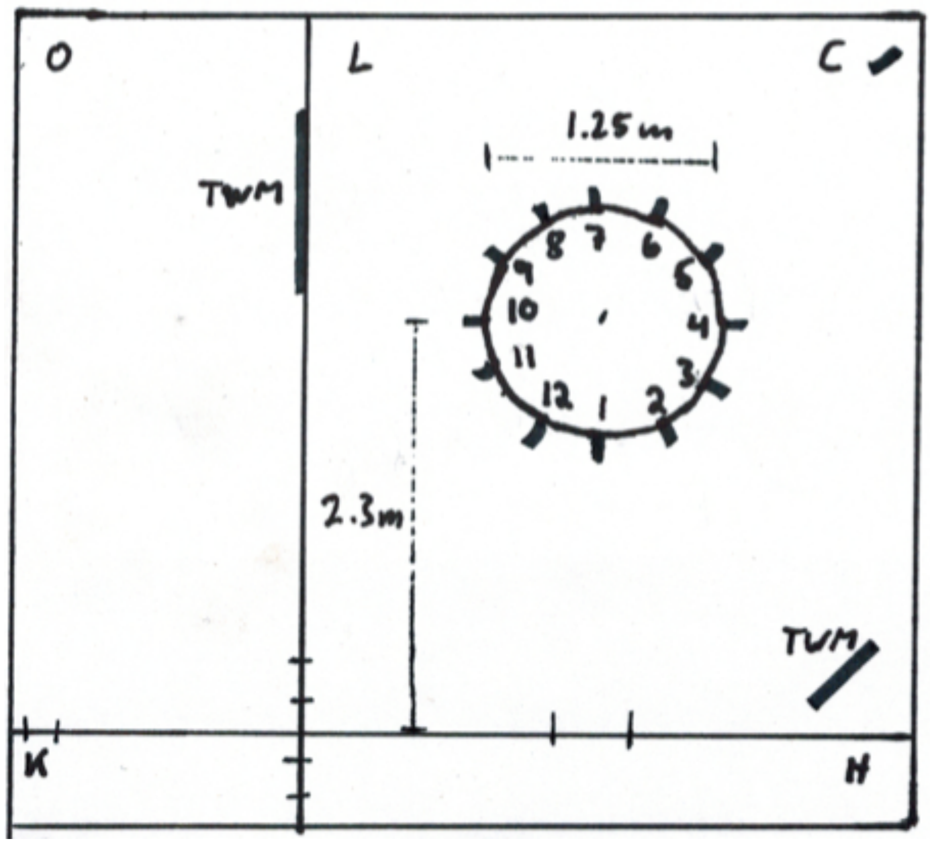

Figure 1: Set up for the multiple choice detection test with the carousel. L = Detection laboratory. O = Observer's office. K = Kitchen. H = Hallway. TWM = Two way mirrors in the wall between the office and the laboratory, and in the screen where the trainer stands. C = Video camera. Scale 1:50.

2.3 Reward preference test

2.3.1 Pre-training

The preference test was done as an indirect test of preference to test how willing the dogs were to work for the two reward types as they were used later in the multiple choice detection test. The sausage or toy itself is not the reinforcer, but rather the dog's behavior when interacting with it (Premack 1959).

The dogs were trained to go to and stay on two differently colored target mats sized 28x40 cm. One mat had a white spot diameter 12 cm on black background (named "white"), the other mat had a black spot on white background (named "black"). Galarce et al. (2007) found that outcome-specific, classically conditioned cues affects the operant response. Therefore I chose to use a different tone to predict each reinforcer. The duration of each tone was 0,5 s. The actual frequency of each tone has not been measured, but the dogs had not previously experienced the two tones. When the dogs performed the target behavior on “white”, a low pitched tone followed by a food reward. Target behavior on “black” was reinforced by a high pitched tone followed by the Kong toy. When the dog reached the criteria for reinforcement (stand, sit or lie still with physical contact with one mat for one second), the tone sounded and immediately after the tone stopped, the reward was thrown to the dog. The trainer remained as motionless as possible after throwing the Kong or food, and was instructed to keep his arms on his back and look straight ahead to avoid gazing or pointing. No social interaction like praise, petting or tug-of-war was used.

Each mat was trained separately until the dogs performed the target behavior in at least 80 % of the trials in one session. Each session lasted for maximum five minutes and between ten and twenty trials were done in each session. Each dog got eight sessions over two days. The number of each reinforcer type used, and the placement of each mat was balanced over sessions. The dog’s running order was rotated for each session, the first dog in session 1 started as number two the second session, number three the third session etc. Over the eight sessions, Fly had a total of 140 training trials, Pryor 110, Caso and Codex 120, Cosmo and Kill 80, Coffie 158 and Cora 124.

2.3.2 Testing

The preference test was done over two days, starting the following day after the preference pre-training was finished. The two mats were placed on the floor with 1,3 m distance between them, and the dogs were let in through a door 2,1m from the mats (figure 2). The trainer stood behind the dogs in the doorway and reinforced the target behavior by throwing Kong or food to the dogs after the tone, following the same instructions as mentioned above.

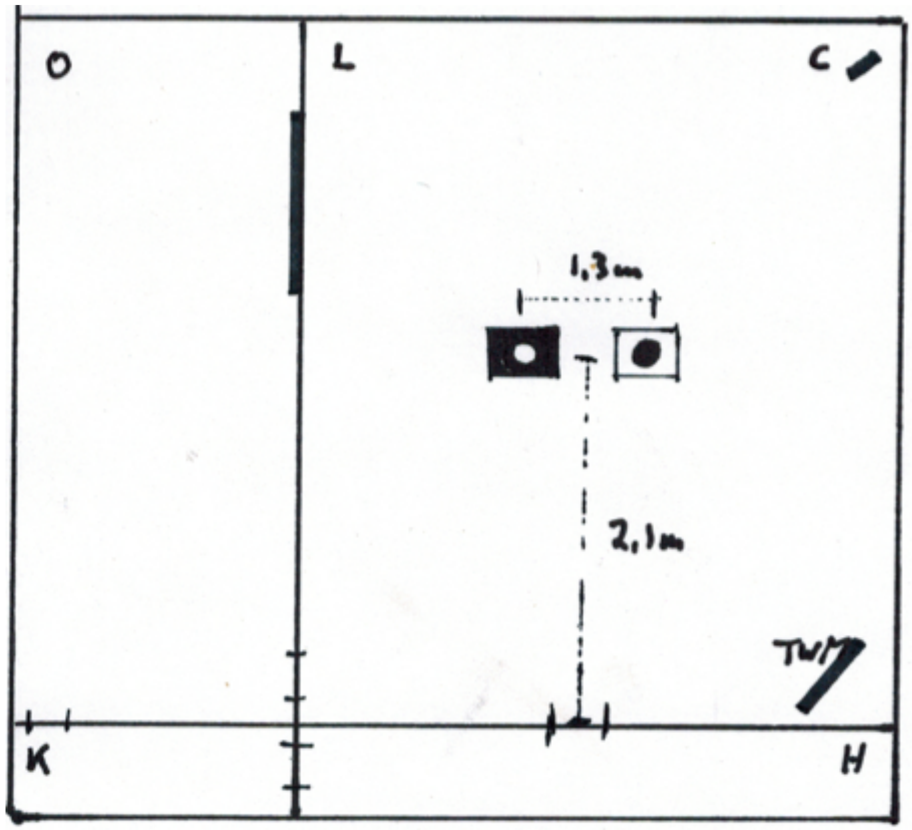

Figure 2: Set up for the Preference test with the placement of the two mats. L = Detection laboratory. O = Observer's office. K = Kitchen. H = Hallway. TWM = Two way mirror screen. C = Video camera. Scale 1:50.

Each dog's preference was tested ten times, five times the first day (part one) and five times the next day (part two). In part one, the "white" mat was to the right and the "black" to the left, and vice versa in part two. To make sure that the dogs made a conscious choice and to balance the number of each reinforcer, the test was conducted in the following manner: In the first trial the dog got to choose one mat. The dog was rewarded and taken out of the room for one minute. The chosen mat was removed and a "forced" trial on the non-preferred mat (rewarded by the other type of reinforcer) was done. In the second trial the dog was asked to choose a mat again, followed by another "forced" run etc. until the dog had chosen five times. The next day the mats switched place and another five tests were conducted.

2.4 Multiple-choice detection test

2.4.1 Pre-training

In previous training done by the FDTA, the dogs had been trained to search and mark a 0,1 gram piece of rubber hidden in pure sand in a aluminum container (the positive sample) among 11 negative samples containing only sand. The criterion for reinforcement was that the dog indicates by sitting down and pointing its nose towards the positive sample. The dog should hold this position for 1 second.

2.4.2 Testing

All data measuring the dogs detection performance were sampled from their work on the multiple-choice carousel during a period of eight days. The multiple-choice detection test started the following day after the preference test was finished. Each dog got one session every day. The dogs were divided into two blocks; Fly, Pryor, Caso and Cosmo in block 1, Codex, Kill, Cora and Coffie in block 2. Day 1, 3, 5 and 7 the Kong was exclusively used as reward for block 1, while block 2 was exclusively rewarded with food. Day 2, 4, 6 and 8 food was used for block 1, while block 2 were rewarded with the Kong. The dogs were taken in for testing in a rotating manner (table 2). The first dog at day 1 started as number two the second day, number three the third day etc. Every second day, the size of the rubber piece in the positive sample decreased (0.1g day 1 and 2, 0.05g day 3 and 4, 0.01g day 5 and 6, 0.005g day 7 and 8).

All the disposable aluminum containers were half-filled with sand and packed in polystyrene boxes the evening before testing. The rubber pieces were cut from a new Kong toy with a scalpel and weighed on a digital 0.1 milligram scale. The positive samples were loaded with the rubber piece and packed in separate boxes. All handling was done wearing disposable rubber gloves and the rubber pieces were handled with a pair of clean tweezers. The carousel was loaded with new samples for each session. For every new dog the arms of the carousel were cleaned and the floor was washed.

Table 2: Running order (Red=Kong, **Blue=Food**)

Day	1	2	3	4	5	6	7	8
Target size (g)	0,1g	0,1g	0,05g	0,05g	0,01g	0,01g	0,005g	0,005g
Running order	Fly	Cora	**Coffie**	Kill	**Codex**	**Cosmo**	Caso	**Pryor**
	Pryor	**Fly**	**Cora**	Coffie	**Kill**	Codex	Cosmo	**Caso**
	Caso	**Pryor**	Fly	Cora	**Coffie**	Kill	**Codex**	**Cosmo**
	Cosmo	**Caso**	Pryor	**Fly**	**Cora**	Coffie	**Kill**	Codex
	Codex	**Cosmo**	Caso	**Pryor**	Fly	Cora	**Coffie**	Kill
	Kill	Codex	Cosmo	**Caso**	Pryor	**Fly**	**Cora**	Coffie
	Coffie	Kill	**Codex**	**Cosmo**	Caso	**Pryor**	Fly	Cora
	Cora	Coffie	**Kill**	Codex	Cosmo	**Caso**	Pryor	**Fly**

Each dog got a session of 13 trials each day. In the first 10 trials, one of the 12 samples was positive. The position of the positive sample was random, and the distribution of the positive sample in trials was changed every second day. Each dog's first rewarded trial was to let the dog know which reinforcer to expect. In the last three trials ("washout period") were all 12 samples negative and therefore not rewarded. Data from the first rewarded trial and the two last in each session were not included in the analysis as the responses can't be considered to be a function of the explanatory variables.

The procedures for the test were a modified version of the general operational procedures used by the Norwegian People's Aid and Geneva International Centre for Humanitarian Demining in Morogoro, Tanzania (GICHD 2006). If there is a hit (see definitions in table 3), the trainer pushed the button for the secondary reinforcer tone (high pitched tone for Kong, low pitched tone for food). The tone lasted for 0.5 s. Immediately after the tone, the trainer threw the toy or food from behind the screen with the two-way mirror into a defined area in one corner of the room. No social interaction like praise, petting, eye-contact or tug-of-war was used.

Table 3: Ethogram with definitions for the Multiple-choice Detection test. SR=Search reliability, TE=Time efficiency, SP=Search pattern

Behavior or measurement	Definition	Variable in analysis of
Trial	Single rewarded or non-rewarded unit	
Session	Each session contains of several trials	
Indication	The dog indicates a sample by sitting down for one second while pointing its nose towards it	
Hit	Indicates (correctly) a positive sample (yes (1) or no (0))	SR
Miss	Does (incorrectly) not indicate a positive sample (yes (1) or no (0))	SR
False alert	Indicates (incorrectly) a negative sample (yes (1) or no (0))	SR
Correct rejection	Does (correctly) not indicate a negative sample (yes (1) or no (0))	SR
Time	Time (in s) from when the trainer released the dog to search and is ended when the secondary reinforcer tone sounded (if rewarded) or until the trainer calls the dog's name (if not rewarded, either when there is a false alarm, the dog has searched one whole round around the carousel or when times is out). Maximum time per run is 20 s.	TE
Start of search	The first sample on the carousel which the dog is in physical contact with	
Passes	Number of samples the dog goes past before starting to search	SP
Unsystematic	The sum of the events jumps, past and back and clockwise	SP
Jumps	The event when the dog is not in physical contact with one or more samples during search	SP
Past and back	A dog sniffs the next sample and returns to indicate the positive	SP
Clockwise	The event when the dog goes clockwise around the carousel	SP

Each trial ended either when the secondary reinforcer tone sounded if dog was rewarded for a hit or by the trainer called the dog's name with a neutral tone if not rewarded and letting it out of the room (if there was a false alarm, the dog had gone one round around the carousel after it had started to search or the time limit for each trial of 20 s had been reached). The time was measured manually with a stop-watch. If the dog hadn't searched the positive sample (jumped it) after completing one round around the carousel, the dog was taken out of the room. All samples that the dog had searched were removed, and the dog got another visit. Each trial could contain of maximum three visits.

2.5. Statistical analysis

2.5.1 Tests

The data from the preference test were analyzed with a binomial test in excel. The binomial test gives sharp cut offs. For p=0.05, seven out of ten choices in favor of one reward type would have given a non-significant preference. I considered this too conservative. Therefore, the chosen level of significance was p=0.1.

All data from the multiple choice detection test were analyzed using the lme4 package in R version 2.15.3 (R 2013). Table 4 shows the four possible outcomes for search reliability – hit, miss, false alert and correct rejection (defined in table 3). Two out of the four outcomes, hits and false alerts, provided independent information about the dog's performance.

Table 4: The four possible outcomes of a search.

Samples	*Response*	
	Indicates "Yes"	Indicates not "No"
Positive	Hit	Miss
Negative	False alert	Correct rejection

Hits and False alerts and were analyzed by binomial Generalized Linear Mixed Models (glmer) using the logit link and fitted by the Laplace approximation.

Time efficiency was measured as time in s. I plotted the residuals versus fitted which showed no pattern, and thus considered normally distributed. Time was analyzed by Linear Mixed Models (lmer) fitted by REML.

The search pattern was evaluated in two parts. The pattern before the search started was measured as the numbers of samples passed. During search, the events jumps, past and back and clockwise were counted. Because the occurrence of the three latter events was rare, they were pooled together and called "unsystematic". The search pattern was analyzed by poisson Generalized Linear Mixed Models (glmer) using the logit link and fitted by the Laplace approximation.

Reward type and reward preference were the two main fixed effects in all models. Dog was nested within sex and breed type (spaniel and retriever), and was included as a random effect in the models. I included the random effect to reduce noise, to define the repeated measure and nested structure in the experimental design and to account for pseudoreplication.

Likelihood ratio tests (LRT) were used for model selection, to assess the significance of possible interactions and to obtain p-values for the fixed effects. The p-values obtained from LRTs might be inaccurate for small sample sizes and should be interpreted with caution. There was no significant interaction between the two main fixed effects for any model. Due to the dog's rising expectations or possible satiation during subsequent trials, the effect of reward type was expected to change with trial number within session (n=9 for hit, n=10 for false alert). Therefore the interaction between reward type and trial number within session was included in the models for hit (χ^2_2 =217.45, $p < 0.001$, false alert (χ^2_2 = 9.23, $p = 0.009$), time (χ^2_2 = 26.80, $p < 0.001$) and passes (χ^2_2 = 32.47, $p < 0.001$). In the model for "unsystematic", this interaction was not significant (χ^2_2 = 1.51, $p = 0.470$). Even though it is considered conservative, the Bonferroni method was applied to counteract the chance of type 1 errors. The chosen probability for significance was 0.05/5 =0.01(α=0.05 divided by the number of hypotheses (n=5) tested).

2.5.2 Models

I planned to use the following five models:

1) «Hit» (Search reliability)

$Y_{ijk} = \mu + R_i + P_j + R{:}T_{(ij)k} + (1|B_m/S_n/C_o)$

where,

R = Reward type	i=1,2 fixed
P = Preference	j=1,2 fixed
T = Trial number within session	k=1 ... 9 fixed
B = Breed type (spaniel, retriever)	m=1,2 random
S = Sex	n=1,2 random
C = Dog	o=1 ... 8 random

2) «False alert» (Search reliability), 3) «Time» (Time efficiancy) and 4) «Passes» (Search pattern)

$Y_{ijl} = \mu + R_i + P_j + R{:}T_{(ij)l} + (1|B_m/S_n/C_o)$

where,

R = Reward type	i=1,2 fixed
P = Preference	j=1,2 fixed
T = Trial number within session	l=1 ... 10 fixed
B = Breed type (spaniel, retriever)	m=1,2 random
S = Sex	n=1,2 random
C = Dog	o=1 ... 8 random

5) «Unsystematic» (Search pattern)

$Y_{ij} = \mu + R_i + P_j + (1|B_m/S_n/C_o)$

where,

R = Reward type	i=1,2 fixed
P = Preference	j=1,2 fixed
B = Breed type (spaniel, retriever)	m=1,2 random
S = Sex	n=1,2 random
C = Dog	o=1 ... 8 random

2.5.3 Hypotheses

2.5.3.1 Search reliability

1. H_0: Hit (Kong) = Hit (Food)
2. H_0: Hit (Preferred) = Hit (Non-preferred)
3. H_0: False alert (Kong) = False alert (Food)
4. H_0: False alert (Preferred) = False alert (Non-preferred)

2.5.3.2 Time efficiency

5. H_0: Time (Kong) = Time (Food)
6. H_0: Time (Preferred) = Time (Non-preferred)

2.5.3.3 Search pattern

7. H_0: Passes(Kong) = Passes (Food)
8. H_0: Passes (Preferred) = Passes (Non-preferred)
9. H_0: Unsystematic (Kong) = Unsystematic (Food)
10. H_0: Unsystematic (Preferred) = Unsystematic (Non-preferred)

3. Results

3.1 Reward preference test

The dogs' preference is shown in table 5.

Table 5: Results of the preference test (K=Kong, F=Food)

Trial	Fly	Pryor	Caso	Cosmo	Codex	Kill	Coffie	Cora
1	F	F	K	K	K	K	F	F
2	F	F	K	K	K	K	F	F
3	F	F	K	K	K	F	F	F
4	F	K	K	K	K	K	F	F
5	F	F	K	K	K	K	F	F
6	K	F	K	F	K	K	F	F
7	K	F	K	K	K	K	F	F
8	F	F	K	K	K	F	F	F
9	F	F	K	K	K	K	F	F
10	K	F	K	K	K	K	F	F
Ratio K/F	3/7	1/9	10/0	9/1	10/0	8/2	0/10	0/10
Preference	F	F	K	K	K	K	F	F

There was a significant preference ($p < 0.1$) if the dog chose one mat before the other 7 or more times (cumulative binomial distribution $P(_{k=7})=0.94$, n=10, p=0.5).

3.2 Multiple choice detection test

3.2.1 Search reliability

Descriptive statistics for search reliability outcomes for reward type and preference are shown in table 6 and 7, respectively.

Table 6: Count (n) of search reliability outcomes for reward type (Kong and Food).

Samples	*Response*					
	Indicates "Yes"		Indicates not "No"		Total	
Positive	Hit		Miss			
	228	228	31	27	259	255
Negative	False alert		Correct rejection			
	6	10	1832	1869	1838	1879
Reward type	Kong	Food	Kong	Food	Kong	Food

Table 7: Count (n) of search reliability outcomes for reward preference (preferred and non-preferred).

Samples	*Response*					
	Indicates "Yes"		Indicates not "No"		Total	
Positive	Hit		Miss			
	229	227	27	31	256	258
Negative	False alert		Correct rejection			
	15	1	1812	1889	1827	1890
Reward type	Pref	Non-pref	Pref	Non-pref	Pref	Non-pref

Table 8 shows that the false alert rate was 0.002 higher for reward type food, and for preference, a higher false alert rate (0.007) when the preferred reward was used. There was no striking difference between the hit rates. The sensitivity measure d' ("dee-prime") allows the hit rate and false alert rate to have equally importance (Macmillan 2005), as it is important that the dogs both indicate positive samples correctly and don't indicate the negative. A higher hit rate leads to higher sensitivity, and a higher false alert rate means less sensitivity. The low false alert rate for the non-preferred reward leads to a high d'.

Table 8: Descriptive statistics for search reliability. H is the hit rate, the proportion of positive samples which the dogs indicated, F is the false alert rate, the proportion of negative samples which the dogs indicated (incorrectly). d' ("dee-prime") = z(H) – z(F). z(H) and z(F) is the z transformation of the hit and false alert rates to a z score (standard deviation units). A rate of 0.5 equals a z score of 0, larger rates to a positive z score, and smaller to a negative. If the dogs couldn't discriminate at all, d'= 0. If z(H) = 0.99 and z(F) = 0.01, d' = 4.65, which is considered an effective ceiling. Perfect accuracy implies an infinite d'. (Macmillan 2005).

	Reward type		Reward preference	
	Kong	Food	Preferred	Non-preferred
H	0.880	0.894	0.895	0.880
F	0.003	0.005	0.008	0.001
d'	3.896	3.803	3.650	4.449

I neither found any difference in hits between the two reward types (GLMM, χ^2_1= 0.83, p = 0.362), nor between the preferred and the non-preferred reward type (GLMM, χ^2_1= 0.04, p = 0.846).

Figure 3 shows how the mean false alerts were distributed in relation to the trial number within session for the two reward types. For reward type Kong, the false alerts occurred late in the sessions. For reward type food, the false alerts showed no striking pattern.

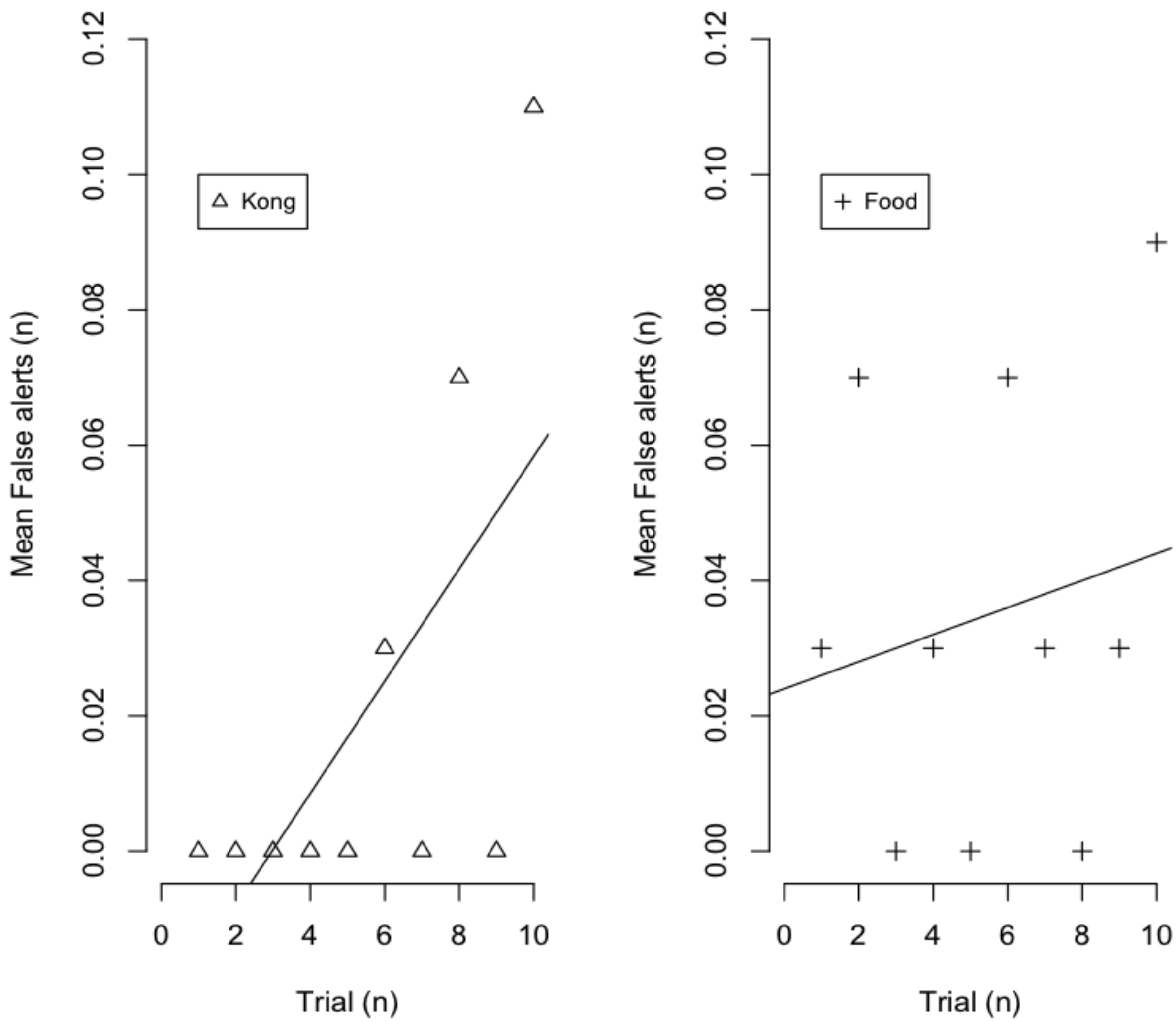

Figure 3: The distribution of mean false alerts over trial numbers for the two reward types, Kong and food rewards, respectively.

The distribution of mean false alerts showed no obvious pattern when the preferred reward was used, but there largest means occured at higher trial numbers (figure 4). For the non-preferred reward, there was only one false alert (table 7), which happened in the second trial in a session.

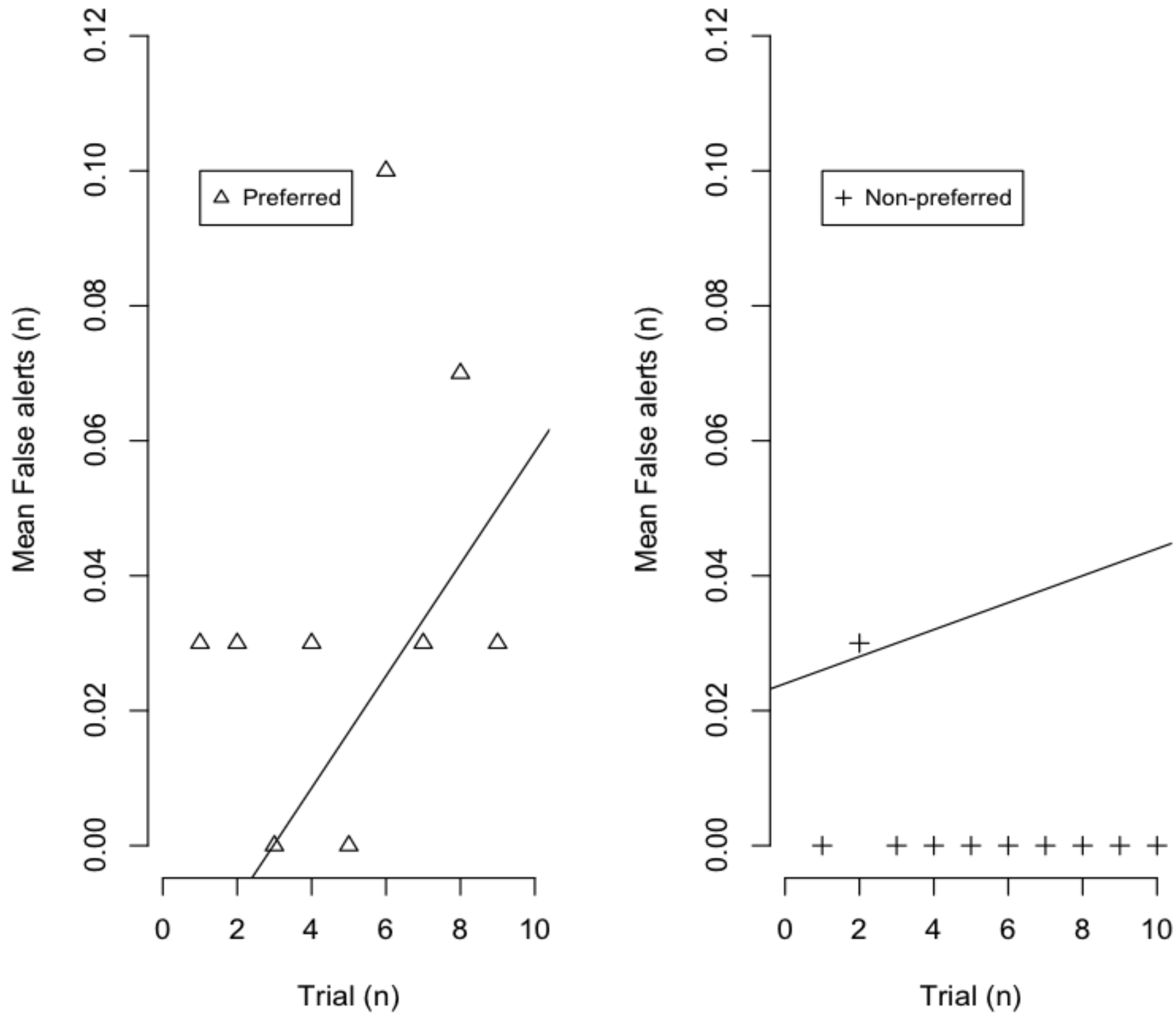

Figure 4: The distribution of mean false alerts over trial numbers for the reward preference, the preferred and non-preferred reward, respectively.

For the effect on false alerts, I found a difference between how the two reward types affected the occurrence (GLMM, χ^2_1= 7.28 p= 0.007). The probability for a false alert when Kong was used was about 0.03 ‰, and when the reward type was food, 2.2 ‰. I also found a difference between the preferred and the non-preferred reinforcer's effect on false alerts (GLMM, χ^2_1= 14.90, p < 0.001). The probability for a false alert was about 4 % with the preferred reward and about 0.2 % with the non-preferred. These probabilities should be interpreted with caution due to the small sample size. I was not able to calculate meaningful and reliable standard errors for the backtransformed probabilities. The log-transformed standard errors are quite large implying large spread.

3.2.2 Time efficiency

Figure 5 show how the effect of reward type Kong on time increased with trial numbers, while there was no striking pattern for mean time and food.

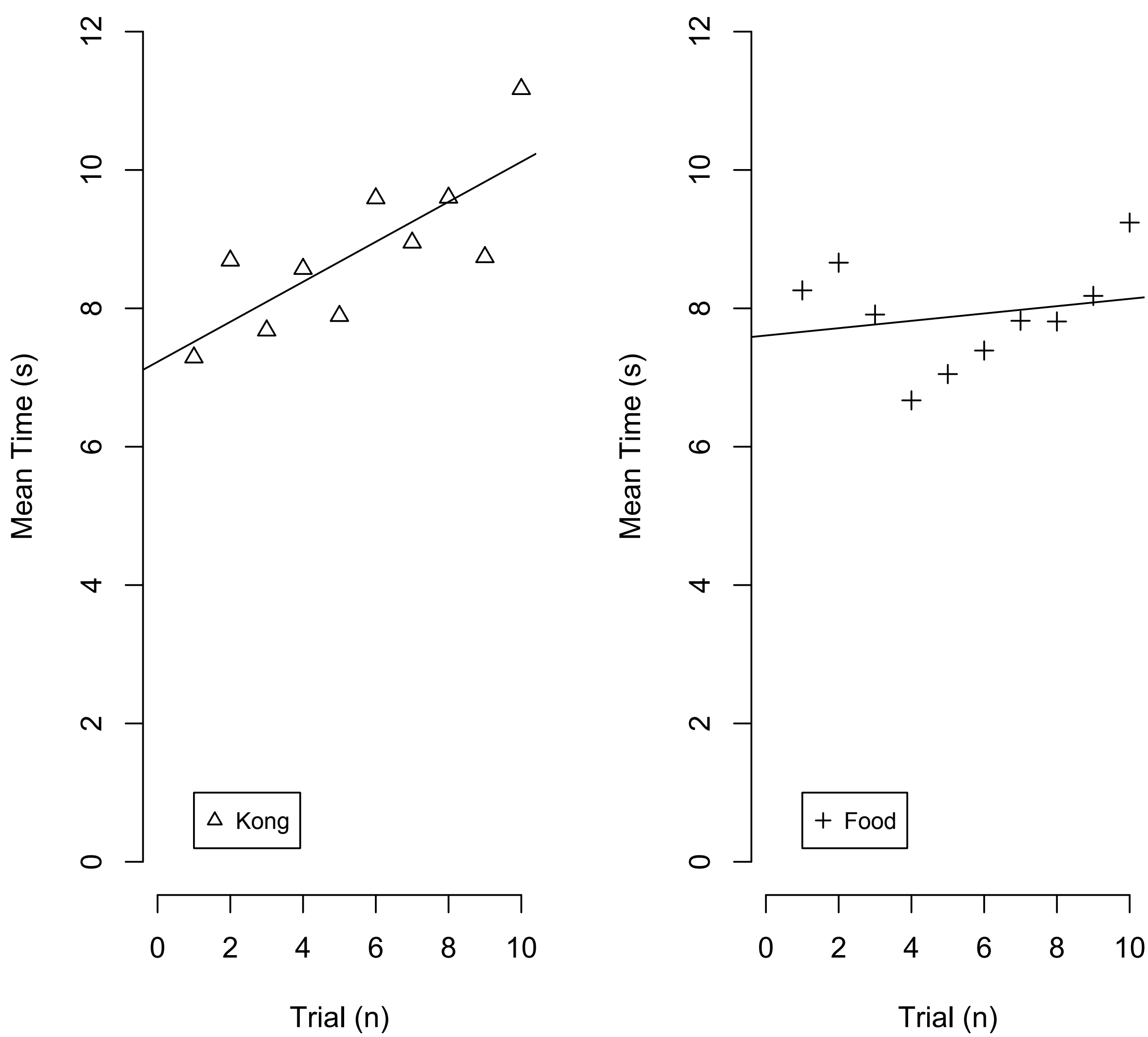

Figure 5: The distribution of mean time over trial numbers for the rewardtype, Kong and food rewards, respectively.

Figure 6 shows how the effect of reward preference over time changes with trial numbers. There is no increase in effect for the preferred reward, while the effect increases with trial number when the non-preferred reward is used.

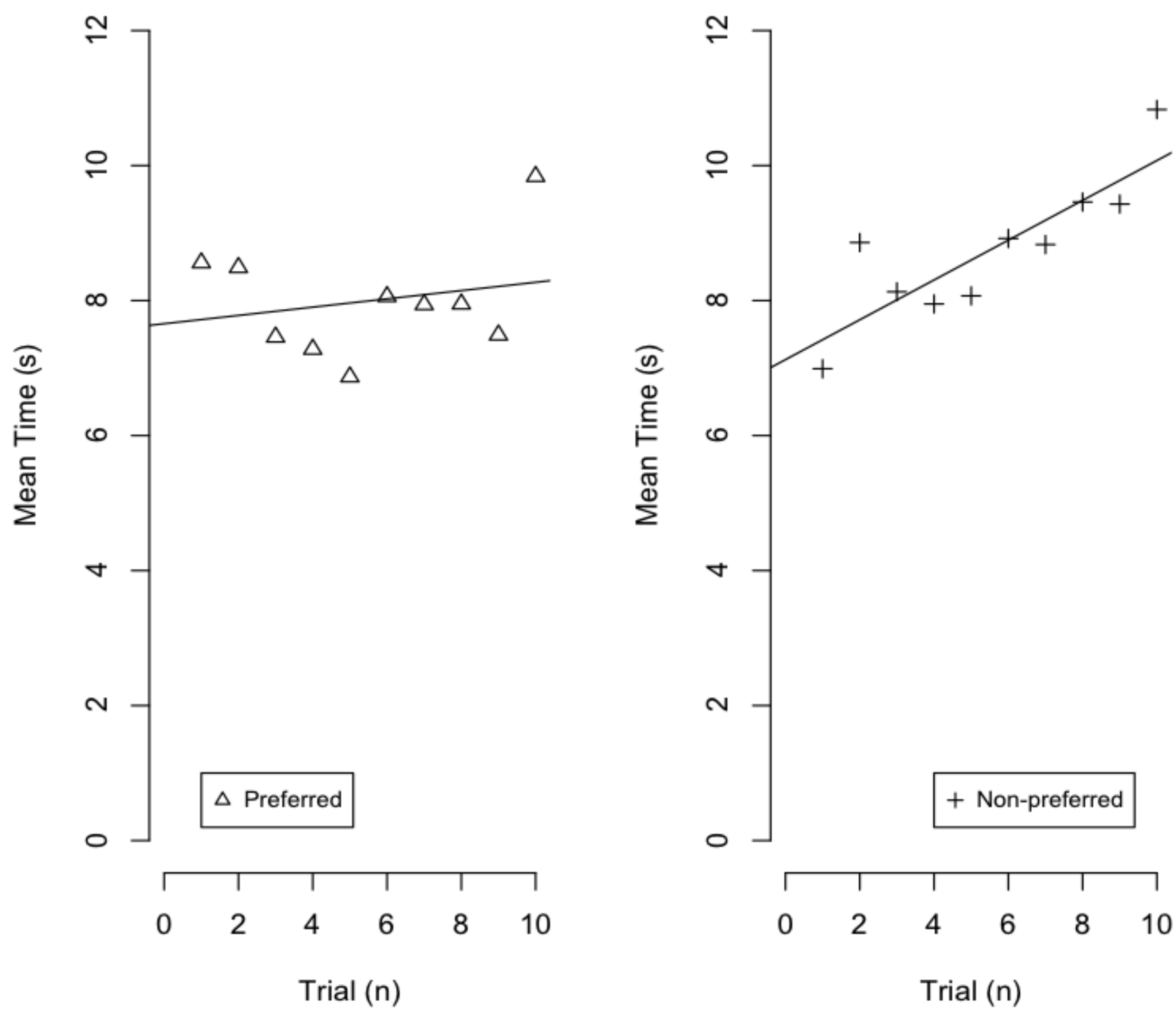

Figure 6: The distribution of mean time over trial numbers for the reward preference, the preferred and non-preferred reward, respectively.

The mean time for reward type was 9.3 s for Kong and 8.3 s for food, although the difference between reward types was not significant (GLM, χ^2_1= 0.99, p= 0.32). The mean when the preferred reinforcer was used was 8.5 s, and 9.1 s for the non-preferred. I found a tendency that the preferred reward affected time (GLM, χ^2_1= 3.93, p= 0.047), decreasing it by about 0.5 s ± 0.3 (standard errors) compared to the non-preferred.

The medians and spread in the data are shown in the boxplots in figure 7. The median for food was 7.8 s and 8.9 s for Kong. For preferred it was 8.2 s and 8.6 s for non-preferred. The interquartile range was 4.5 s for Kong and non-preferred, and 3.8 s for food and preferred. The spread was limited by the maximum time of 20 s.

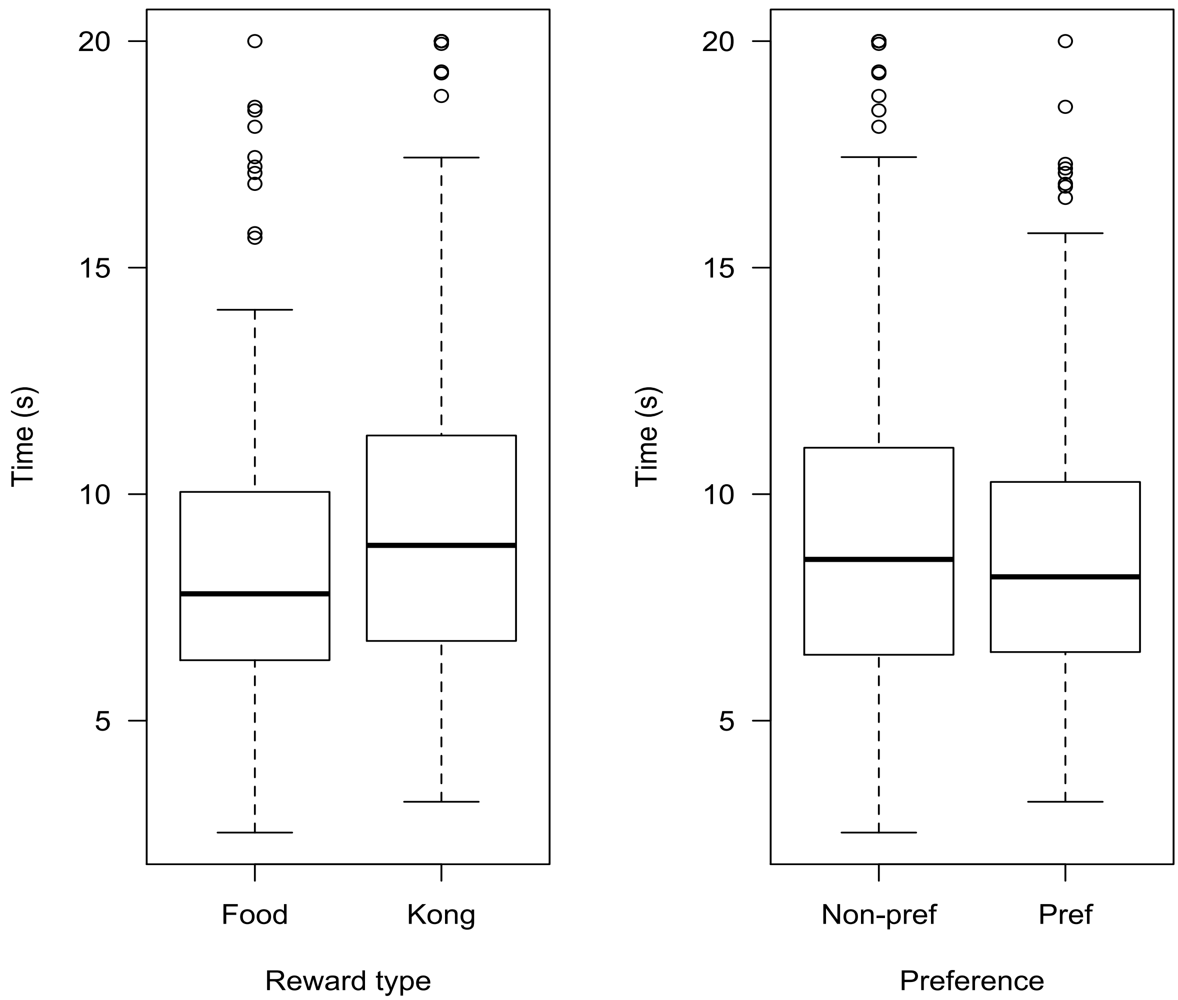

Figure 7: The box shows the interquartile range that contains values between 25th and 75th percentile. The line inside the box show the median. The two "whiskers" show adjacent values. The upper adjacent value (upper mark) is the value of the largest observation that is less than or equal to the upper quartile plus 1.5 the length of the interquartile range. Analogously the lower adjacent value (lower mark) is the value of the smallest observation that is greater than or equal to the lower quartile less 1.5 times the length of interquartile range. Outliers are observations outside lower-upper mark range.

3.2.3 Search pattern

3.2.3.1 Passes

In figure 8 we see how mean passes increased with trial number within session when the reward type was Kong. For food, mean passes decreased.

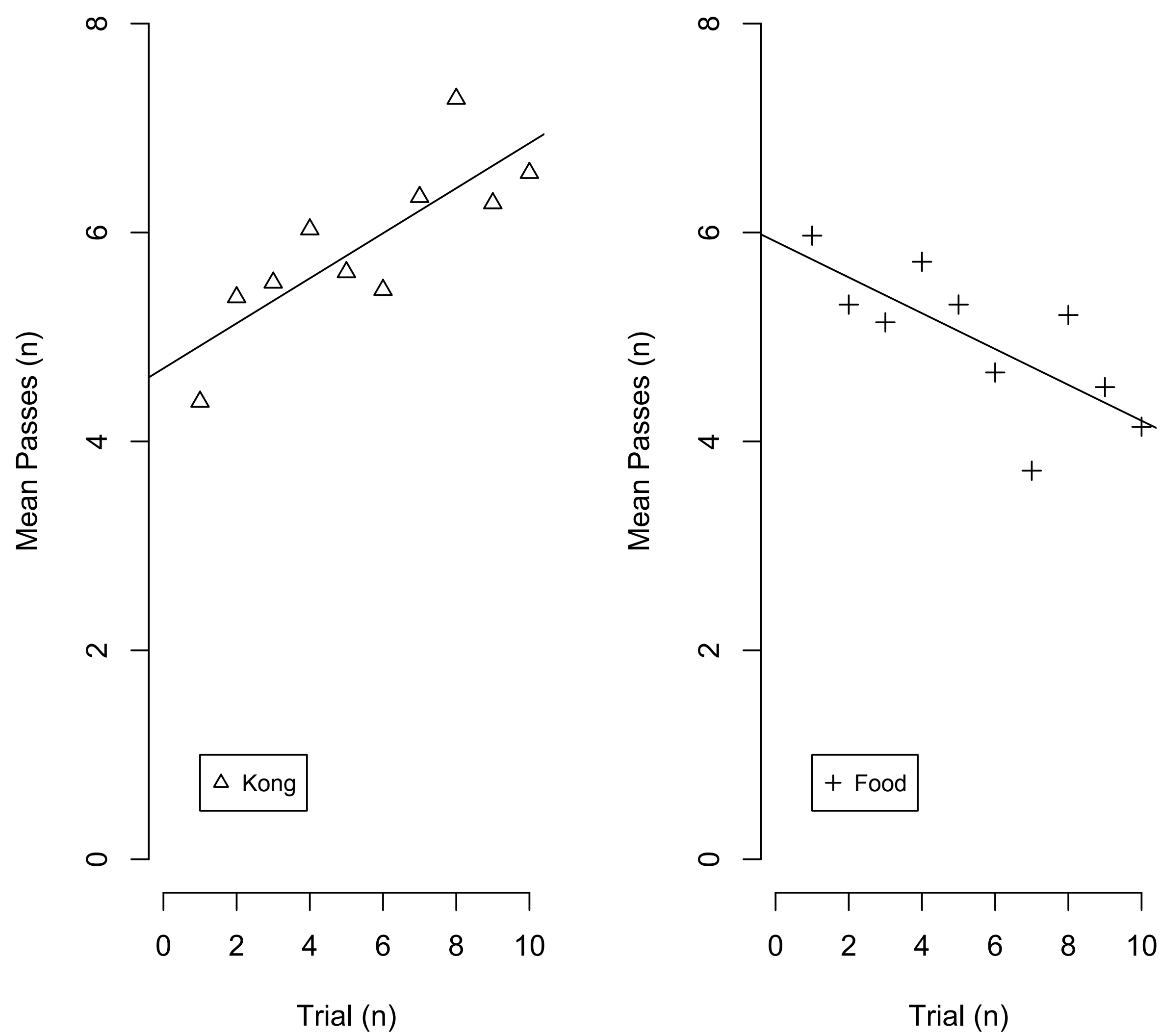

Figure 8: The distribution of mean time over trial numbers for the reward types, Kong and food rewards, respectively.

There was no such striking effect on mean passes when we look at reward preference (table 9). There might be a slight increase for mean passes when the non-preferred reward was used.

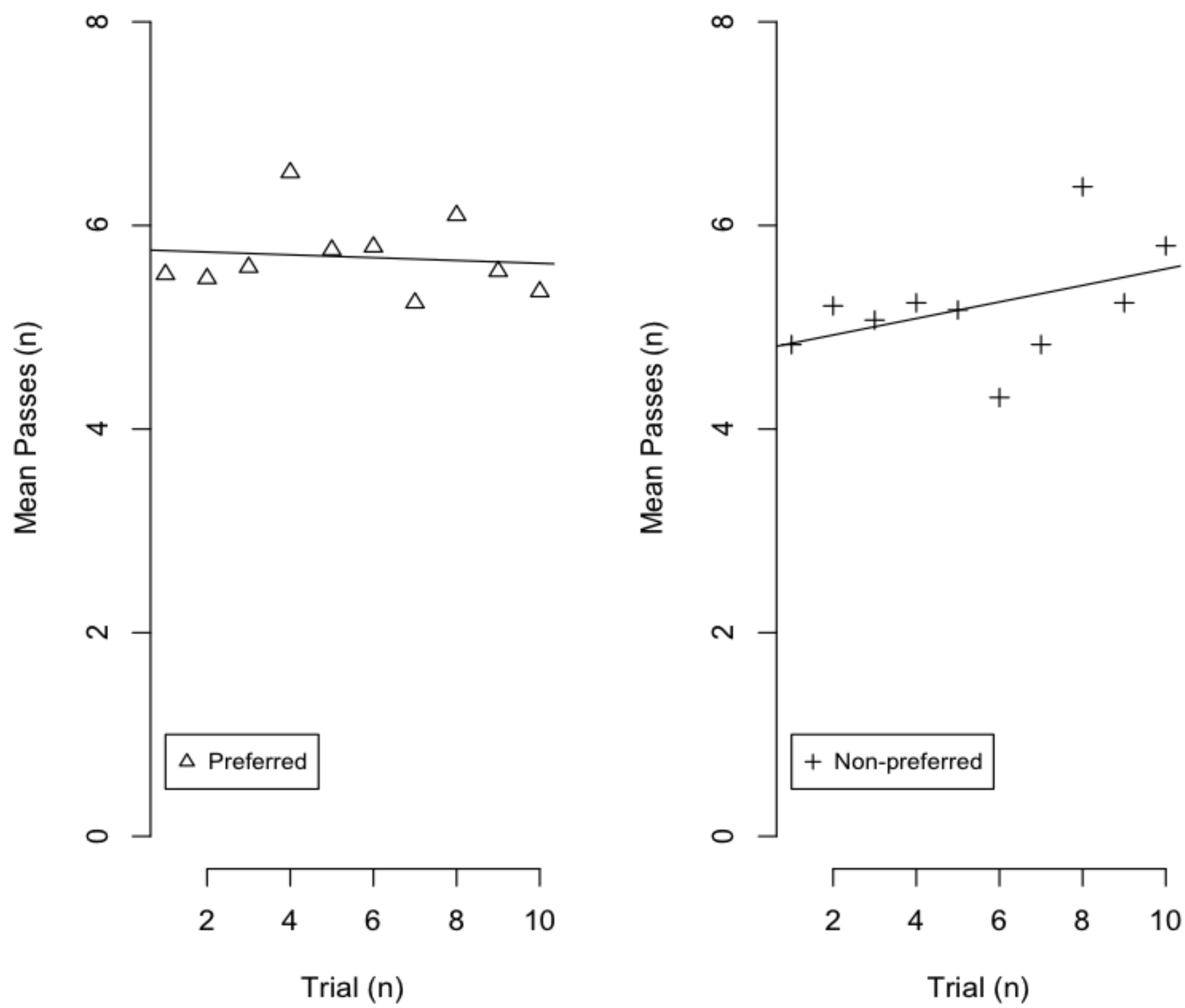

Figure 9: The distribution of mean passes over trial numbers for the reward preference, the preferred and non-preferred reward, respectively.

The mean number of passes for reward type from my data was 5.9 for reward type Kong and 5.0 for food. I found a difference between reward types (GLMM, χ^2_1= 7.84) p= 0.005). According to the model, the estimated number of passes when reward type Kong was used, was 4.4 (-1.1 and +1.6 standard errors). When food was used as reward, the estimated passes were 5.1 (-1.0 and +1.3 standard errors). The standard errors are asymmetric due to the anti-log backtransformation. The findings suggested that reward type food leads to an increase in samples passed with 0.7. The mean number of passes for preference was 5.7 for the preferred reinforcer and 5.2 for the non-preferred. A significant difference was found (GLMM, χ^2_1= 7.28, p= 0.007). The estimated number of passes when the preferred reinforcer was used was 5.9 (-1.4 and +1.6 standard errors). For the non-preferred reinforcer, the estimated number of passes was 5.3 (-1.0 and + 1.3 standard errors), indicating that the preferred reinforcer lead to an increased number of samples passed with 0.6. The medians and spread in the data are shown in the boxplots in figure 10. The median for food is 4 passes and 5 passes for Kong. For preferred it is 5 passes and 4 passes for non-preferred. The interquartile range was 5 passes for all.

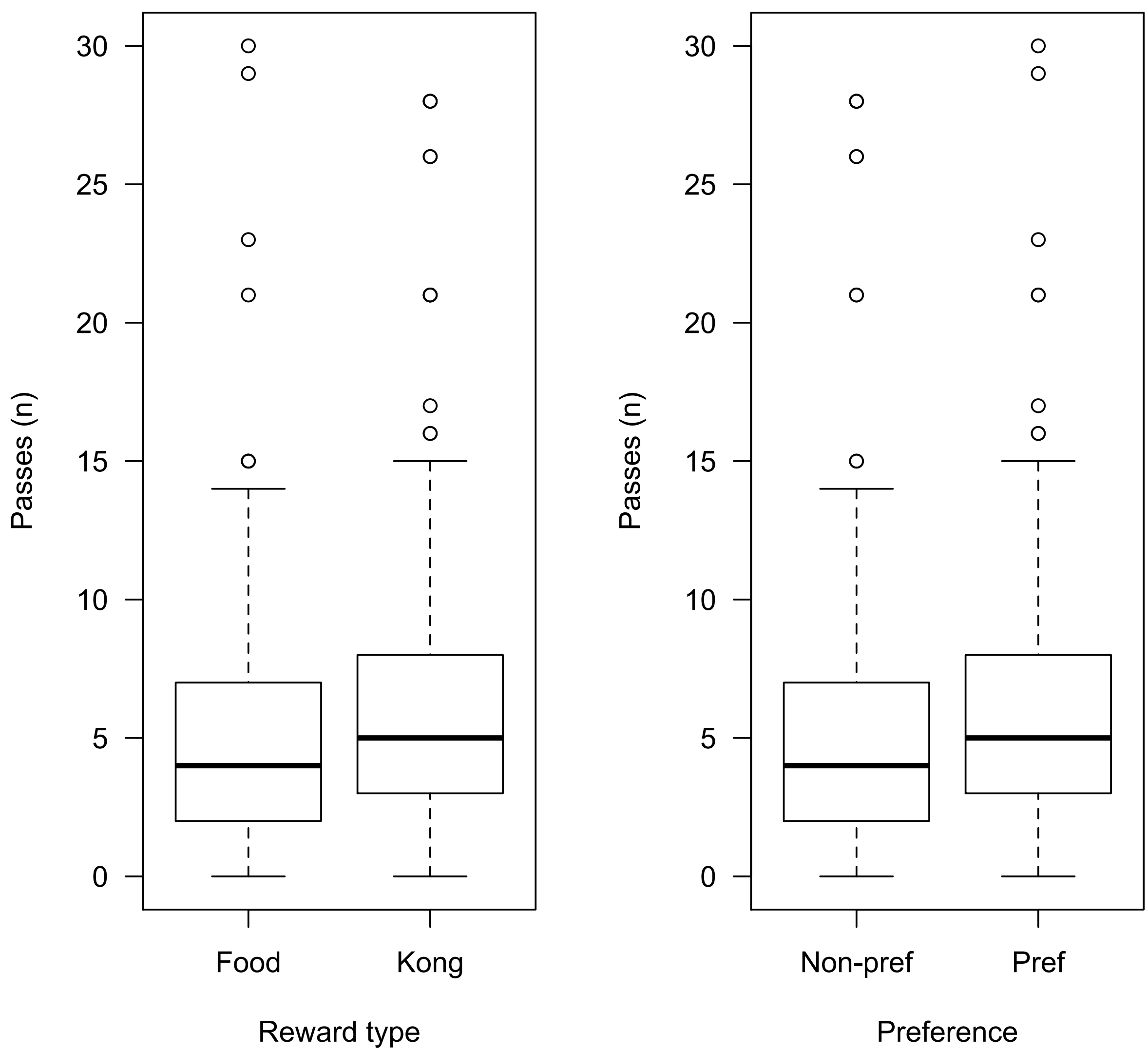

Figure 10: The box shows the interquartile range that contains values between 25th and 75th percentile. The line inside the box show the median. The two "whiskers" show adjacent values. The upper adjacent value (upper mark) is the value of the largest observation that is less than or equal to the upper quartile plus 1.5 the length of the interquartile range. Analogously the lower adjacent value (lower mark) is the value of the smallest observation that is greater than or equal to the lower quartile less 1.5 times the length of interquartile range. Outliers are observations outside lower-upper mark range.

3.2.3.2 Pattern during search

A summary of the event ”unsystematic” is shown in table 9. There was a higher number of jumps when the reward was food, and the no past and back’s when the preferred reward was used. Overall, the events were quite evenly distributed over the reward types and reward preferences.

Table 9: Counts of the event Unsystematic (during search) which is the sum of the events jumps, clockwise and past and back (see ethogram in table 3) for reward type and preference.

	Reward type		**Preference**	
	Kong	Food	Preferred	Non preferred
Unsystematic	22	26	20	28
Jumps	14	20	16	18
Clockwise	3	4	4	3
Past and back	5	2	0	7

I neither found any effect of reward type (GLMM, χ^2_1= 0.33, p= 0.565), nor any effect of preference (GLMM, χ^2_1= 1.50, p= 0.221) on the occurrence of the event “unsystematic” during search.

4. Discussion

4.1 Reward preference test

In the preference test, all dogs showed a clear preference. The test results matched our general impression of the dogs’ preferences. In the second part of the test when the mats switched place, on one occasion, I observed how one dog chose a mat (the one that produced the non-preferred reward), but the second she chose, right before she was rewarded, she hesitated and from the rapid gaze alternation, it could almost seem like she regretted her choice.

All four bitches preferred food, while all males preferred the Kong, and although this might be the result of chance, and more dogs would be needed to distinguish between a sex effect (if present) and individual preference. Based on experience and empirical evidence, bitches often have a greater appetite than male dogs, but there are differences both between breeds and individuals. Regardless of reward preference, Rooney and Bradshaw (2004) found no difference between the sexes in their suitability as detection dogs.

This study was based on a single period of reward preference assessment before conduct of the multiple-choice detection testing. Thus, it did not take into account the possibility of systematic or fluctuating changes in reward preference during the course of the detection testing. This possibility could be taken into account in future research by performing a preference test before and after each session of multiple-choice detection testing. Although not considered likely to have affected the current results, the possibility of session order and side bias effects should also be taken into account when designing future studies of this type. For example, half of the dogs (randomly chosen) could be assigned to get the white mat on the right, and the other half to get the white mat on the left, counterbalancing mat placement in successive sessions. Similarly, although no sign of any aversive or pleasant association to the tones used to signal the two reward types was observed during the current experiment, this possibility could be ruled out in future research by randomly assigning half of the dogs to get the high pitched tone for Kong reward and the low pitched tone for food, and vice versa for the other half of the subjects.

4.2 Multiple-choice detection test

4.2.1 Search reliability

The hit rates close to 90% and no differences between reward type and preference in the multiple-choice detection test imply that the dogs were trained to a high level before the experiment. One could say that the subjects for the study almost were "too good". However, I was able to reveal some differences in false alert rates. Although all false alert rates were very low, the rates were significantly lower when the Kong or the non-preferred reward was used. If we assume that both chasing the Kong and the allocation of the preferred reward elicit higher levels of arousal than food and the non-preferred reward, respectively, the findings are somewhat contradictory. A higher false alert rate for the preferred reward makes sense according to the Easterbrook (1959) hypothesis. Assuming that the preferred reward makes the dogs more excited than the non-preferred, their ability to discriminate between positive and negative samples decrease when the preferred reward is used. In other words, increasing motivation leads to more false positives (Weiss 2008).The higher false alert rate for food is harder to explain. When food reward was used, there were only 10 false alerts out of 1879 possible, and 6 out of 1838 possible when Kong reward was used (table 6). With such a low occurrence of false alerts, the results must be interpreted with caution, as only one or two changes in behavior from one of the dogs could alter the significance of this finding.

When we take a closer look at how the false alerts were distributed relative to trial number within session (figure 3 and 4), we see that the mean false alerts increase with higher trial numbers both for Kong and the preferred reward. This might be due to the dogs' rising expectations during the session.

The sensitivity measure d' (table 8) is very high (d'=4.449) for the non-preferred reinforcer. This might imply that the dog's favorite reward isn't always the most efficient reinforcer, as Svartberg (2000) suggested, and that the dogs perform better when the non-preferred reward is used. We have to keep in mind that the non-preferred reward in this context is not a reward that is not desirable – it's just less strongly desirable. The dogs in this study were bred for detection work, and were used to and willing to work for both reward types even though they had a clear preference.

4.2.2 Time efficiency

The effect of reward type on time efficiency was not significant. As predicted, the preferred reinforcer produced a lower time score with a decrease of about 0.5 s. The dogs worked faster when their preferred reinforcer was used, while there were no general effects of either Kong or food. Time was measured manually with a stop-watch from when the trainer cued the dogs to search, and until the dogs were rewarded or called out of the room. There is a source of both trainer error and timekeeper error. Therefore we should not put too much emphasis on the actual difference in time score, although the significant difference found from approximately 290 observations for each treatment should account for error in single observations. Ideally, time would be measured electronically both from the moment the trainer cued the dogs to search and at each arm of carousel to measure time per sample searched precisely. Unfortunately this technology was not available for the current study.

From figure 5 we see that mean time increased for higher trial numbers when the reward is Kong, and figure 6 shows a similar effect for the non-preferred reinforcer. This coincides with the trends for mean passes over trial numbers for the reward type Kong. Total time increased when the dogs went past more samples before starting to search. Total time depends in part on the search pattern.

4.2.3 Search pattern

The mean number of samples the dogs ran past before starting to search increased with higher trial numbers for Kong and decreased for food (figure 8). This might be due to higher excitement and levels of arousal with increasing expectations of the Kong reward, while the dogs searched more and more accurately when rewarded with food. Further experiments where the arousal levels are measured, e.g. physiological signs such as heart rate, respiration and biochemistry, or indirect measures of arousal through behavioral observations, need to be done to confirm if this explanation is correct.

No such trends were observed for increasing trial numbers for reward preference (figure 9). There might be a slight increase in effect when the non-preferred reward was used.

The means of samples passed from the data set showed that 0.9 more samples were passed when Kong was used, while the estimated values from the model suggested that 0.7 more samples were passed when the dogs were rewarded with food. The estimated means from the model corresponded well to the observed means for food, preferred and non-preferred, but differed for Kong. The difference between the estimated and observed value of passes for Kong was within one standard error. The large spread implies that the estimate of the population mean is imprecise. A larger sample size in future studies is recommended.

There was a significant difference between the preferred and the non-preferred reward for number of passes. The preferred reward produced 0.6 more samples passed, which might be explained by the "arousal induced sloppiness"-theory, cf. Easterbrook (1959), which states that arousal levels above the optimal range impairs performance.

I found no difference in the pattern during search. The reward type and reward preference affected the starting point on the carousel, but after they started to search the quality of the reward didn't affect their performance.

4.3 Interpretation and suggested future studies

The reward types were contrasted closely in time, which might enhance the differential effect (cf. Crespi (1942), Harzem (1975)). A challenge with within-subject alternating treatment designs is to take the carry-over effect into account. Counterbalancing and adding a wash out period can cope with it. At the time of the experiment, the dogs were at a relative high level of training and the findings should be considered as illustrating effects on performance of steady state behavior, and not on acquisition of new behavior (cf. Crespi (1942) and Davey (1981)). Future studies are needed to investigate the effect of reward types on acquisition of new behavior. I suggest to teach dogs to indicate two different, but equivalent odours, where half of the dogs are rewarded with reward A for indicating odour 1, and reward B is used for odour 2, and vice versa for the other half. The sample size should be large enough to be able to counterbalance for preference and sex differences.

The findings in this study should be interpreted with caution. Few subjects were used and small changes in individual performance could have a large impact on the results. The variation between dogs was quite small as five of them were littermates. From the time when they were young puppies, an effort was made to strengthen their weaknesses when it comes to reinforcer development, socialization and environmental training. Any individuals found to have such extreme weaknesses that they would not be worth the time and effort to train, would have been taken out of the project and sold as pet dogs. All the dogs in the study worked willingly for both reward types and the differences in their performances were quite small. Therefore the results shouldn't be generalized to other kind of dogs, like the average pet dog. Repeated studies with larger sample size and different breeds need to be done to validate the results. Future studies should include both male dogs who prefer food over toys, and bitches who prefer toy rewards over food. This research should also be broadened to examine the effectiveness of additional exemplars of food and toy reinforcers, combined with and without social interaction like praise and tug-of-war, in detecting a variety of different odour targets.

4.4 Concluding remarks

In conclusion, my hypothesis was that there would be differences in detection performance depending on (a) preference for the Kong versus food reward and (b) type of reward (Kong versus food) in general. The dogs confirmed my predictions that the preferred reward produced more false alerts and a less focused search pattern, and that there was an effect of reward type on false alerts and samples gone past before the dogs started to search. Whereas my prediction that there was any effect of preference and a general effect of reward types on hit rate, time efficiency and system during search was not upheld. Therefore, my results provide partial support for my hypothesis. These findings add to general understanding about methods of enhancing performance of highly trained individuals as well as contributing practical knowledge applicable to work with dogs trained for substance detection.

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Appendix I

Photos

Photo 1: Medium sized Kong used as toy reward (Photographer: Helena Narjord)

Photo 2: Slices of sausage used as food reward (Photographer Thomas Stokke)

Photo 3: The two mats in the preference test (Photographer Thomas Stokke)

Photo 4: Cocker spaniel Pryor in the preference test. Arranged photo. (Photographer Thomas Stokke)

Photo 5: Rubber pieces 0.1 g used in the positive sample (Photographer Thomas Stokke)

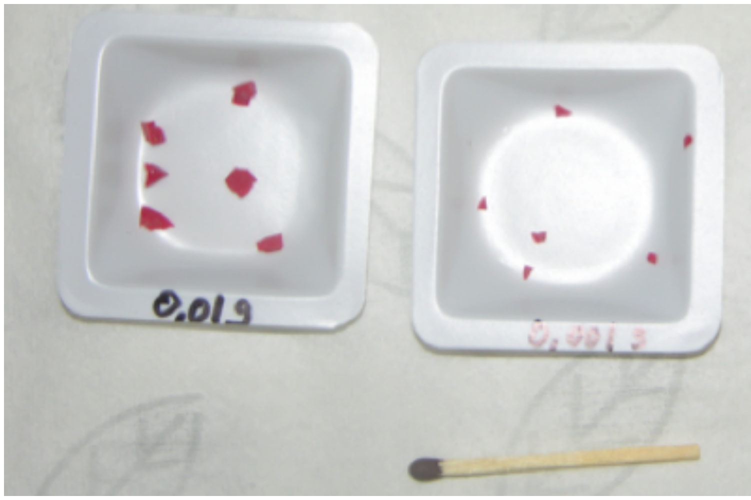

Photo 6: Rubber pieces 0.01g and 0.001g used in the positive sample (Photographer Thomas Stokke)

Photo 7: Springer spaniel Fly working on the carousel. The photo is not taken during the experiment.
(Photographer: Jan Petter Svendal)

Appendix II

Video links showing three of the dogs in the project working on the carousel. The videos are taken in pre-training and not during the experiment.

https://www.youtube.com/watch?v=cjefMl0QbBI

https://www.youtube.com/watch?v=xSnMky7kIT8

https://www.youtube.com/watch?v=EunoyuWwEcc

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