THE USE OF DOGS TO DETECT CARPET BEETLES (*Anthrenocerus australis*)

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Abstract

This study examined the ability of domestic dogs (*Canis familiaris*) to detect the scent of carpet beetle larvae (*Anthrenocerus australis*). These insects were introduced to New Zealand and are now a pest of woollen carpets and fabrics in this country. The use of detector dogs can help with earlier discovery and identification of infested areas and thus reduce the use of pesticides.

Sixteen harrier hounds were available for this study, however only six dogs were selected for the actual trials after initial training. There were four trials, in which the dogs had to detect four different stimuli (dog food A, carpet beetle larvae, cockroaches and dog food B). Each run evaluated whether the dog could identify the target pottle out of six pottles. The other five pottles were empty. A dog completed six runs each day over five days for food A and over three days for the other three stimuli. Therefore there were a total of 30 runs for food A and 18 runs for the rest of the stimuli. A run was considered successful when the dog found the target pottle on the first try (i.e. first pass around the circle) without any false positives (sitting at a pottle that did not contain the stimulus).

The dogs were able to identify dog food A and B with an average success of 74.5% and 78.9% respectively. The detection rate for dog food was significantly higher than would be expected if the dogs were selecting pottles at random ($z \geq 1.64$, $p < 0.05$). However they were unable to identify either the carpet beetle larvae or cockroaches, with an average success of only 27.7% and 45.5% respectively. These results indicate that the dogs were incapable of detecting carpet beetle larvae. This could be due to several reasons such as dog breed, learning inflexibility, handler influences and methodology. The dogs used may have not been the best choice for this experiment, however they were chosen based on availability. The dogs were trained first on food before the insect trials, hence they may not have been able to create a new association between the reinforcer and insect stimuli. The handler and her techniques may have influenced the dogs to select the target pottle unintentionally (e.g. longer pauses at the target pottle) as there was a higher success rate for formal tests compared to blind tests (in which the handler did not know where the target pottle was) ($Z = -3.5$, $p = 0.0005$).

Future studies could look at the ability of other dog breeds to detect carpet beetles. More research should be done on the effects of temperament in scent detection dogs. Future research could investigate if detector dogs can differentiate between different carpet beetle species and if they are able to detect carpet beetles in the field (i.e. in museums or houses).

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Chapter 1

Introduction

Jade. Photo: Chloe Phoon

This research was done for biosecurity and pest management purposes. Biosecurity is very important to New Zealand because of the vulnerability of the endemic species, ecosystems and primary industries (Clout & Lowe, 2000; Bewsell, Bigsby & Cullen, 2012). The aim of this project was to determine the ability of the domestic dog to detect Dermestid beetles. These beetles cause damage to carpets (Robertson, 1949; Scholler et al., 1997), clothes and museum artifacts (Su & Scheffrahn, 1990) and have been known to cause asthma due to an allergen from the larvae in house dust (Cuesta-Herranz et al., 1997).

Excessive use of pesticides can be harmful to the environment (Sundaramurthy, 2002). Therefore dogs trained to detect these insects may assist in their discovery and eradication without the excessive use of pesticides. Such dogs could also be used in border security to make sure that unwanted pests are kept out of this country.

1.1 Biosecurity in New Zealand

Biosecurity is defined by the New Zealand Biosecurity Council as the "exclusion, eradication or effective management of risks posed by pests and diseases to the economy, environment and human health" (Anon, 2003). Pests are any organisms detrimental to humans or human concerns (e.g. agriculture or livestock production), including invertebrates and vertebrate animals, pathogens and weeds (Kogan, 1998). An invasive species is one that is not native to the country and causes adverse effects to either humans or the ecosystem (Jay, Morad & Bell, 2003).

New Zealand has been geographically isolated for almost 60 million years and therefore the native species and ecosystems have evolved without influence of exotic species until relatively recently (Clout & Lowe, 2000; Jay, Morad & Bell, 2003). In the absences of mammalian predators, many endemic New Zealand birds and insects have evolved to be large and flightless (Trewick, 2000; Duncan & Blackburn, 2004). This makes them susceptible to predators, hunting and habitat loss as they do not display predator-avoidance behaviour (O'Donnell, 1996; Duncan & Blackburn, 2004). There is a high rate of extinction when a species evolves on an island because of the restricted distribution it faces (Duncan & Blackburn, 2004). Native plants and animals can also be threatened by interspecific competition caused by the high competitive ability of invasive species for natural resources (Vila & Weiner, 2004).

There have been many incidents in which an invasive species impacted negatively on the flora or fauna of New Zealand. Many species have become extinct because of the introduction of rats and other predatory mammals (Brown, 1989). For example, mustelids such as stoats, weasels and ferrets were introduced to control rabbits; however it was unsuccessful, and they have killed both native and introduced birds (Moors, 1983; O'Donnell, 1996). Introduced fish, such as trout, have replaced nonmigratory galaxiid fish in some streams and have affected the distributions of freshwater crayfish (*Paranephrops zealandicus*) and other large invertebrates (Townsend, 2003). About 1000 native species are considered to have become threatened since the introduction of foreign species in the last 700 years (Jay, Morad & Bell, 2003).

The New Zealand economy relies heavily on agriculture, fishing and forestry and therefore cannot afford the risk of a biological invasion (Bewsell, Bigsby & Cullen, 2012; Trampusch, 2014). Primary products including meat, wool, milk, timber, and fish account for 50% of New Zealand's exports (Jay, Morad & Bell, 2003; Trampusch, 2014). An example of a biosecurity invasion is introduced weeds which have caused significant losses in primary productivity or required major costs to control these pests (Jay, Morad & Bell, 2003). Insects such as aphids have been recorded to invade New Zealand almost every year in the last 130 years although this rate has declined in recent years (Teulon & Stufkens, 2002). These insects enter the country through two main pathways, firstly as passengers on plants and produce and secondly, by wind. They have caused economic damage to plants through their feeding and transmitting plant viruses (Teulon & Stufkens, 2002).

Invasive species can enter New Zealand through various pathways. These include imported goods (e.g. livestock and plants), ships and aircrafts, and shipping containers (Anon, 2003). Tourism is also a major source of income to New Zealand, however, travel has increased the risk of biological invasions (Bewsell, Bigsby & Cullen, 2012; Trampusch, 2014). With increased trade and travel, endemic flora and fauna become more vulnerable to the impacts of exotic and invading species (Clout & Lowe, 2000; Bewsell, Bigsby & Cullen, 2012).

The New Zealand biosecurity system consists of the Biosecurity Act of 1993, a Biosecurity Strategy released in 2003 and the Ministry of Primary Industries (MPI) which is the enforcement agency (Bewsell, Bigsby & Cullen, 2012). The Biosecurity Act of 1993 prohibits the importation of any plants, plant products, animals or animal products to New Zealand unless an import health standard has been issued (Jay & Morad, 2006). Biosecurity also includes dealing with pests or diseases that enter the country and their consequences for the economy and environment, as well as human and animal health (Trampusch, 2014). Such activities range from protecting farms from agricultural pests to preventing insect infestations in museum artifacts (Trampusch, 2014).

There are a range of measures that are used to reduce the risk or consequences of an invasion. These include pre-border, border and post-border strategies (Hall, 2004; Bewsell, Bigsby & Cullen, 2012). Pre-border strategies include checking and treating imported goods, such as fruit, in the country of origin before exportation to New Zealand (Bewsell, Bigsby & Cullen, 2012). Border activities (by air and sea) include the use of x-ray machines, periodically searching bags after passing through x-ray, instant fines for passengers failing to declare organic goods and the use of detector dogs (Anon, 2003; Halls, 2004). Post-border security deals with organisms that have already entered the country. This includes rapid identification of unwanted organisms and eradication responses (Halls, 2004).

1.2 Dogs used to Detect Insects

Dogs (*Canis lupus familiaris*) are a useful detection tool because they have an acute sense of smell. Dogs have been trained to locate both non-biological and biological substances. Non-biological substances include land mines, accelerants, hazardous chemicals and drugs (Browne, Stafford & Fordham, 2006). Biological substances include humans, other mammals, birds and reptiles (Browne, Stafford & Fordham, 2006). They are used in agriculture, conservation, criminal investigations and border control (Browne, Stafford & Fordham, 2006).

Dogs have been used to detect insects for pest management and border control. The first published record of using dogs to detect insects is from 1976 when Wallner & Ellis used domestic dogs to successfully detect gypsy moth (*Porthetria dispar L.*) pheremones and egg masses. Dogs have been used to detect red palm weevil (Nakash, Osem & Kehat, 2000), Asian longhorned beetle (Errico, 2012), fire ants (Lin, et al., 2011), and *Reduviidae* bugs (Rolon, et al., 2011) which are all agriculture pests.

Dogs are able to differentiate between different types of insects (i.e. between different families) and within a species, between different life stages. In one experiment dogs were able to distinguish between bed bugs (target insect) and cockroaches, termites and ants (non-target insects) (Pfiester, Koehler & Pereira, 2008). They were also able to differentiate between live bed bugs and dead bugs, cast skins and faeces. A pseudoscent prepared from pentane extraction of bed bugs was also recognized by the dogs (Pfiester, Koehler & Pereira, 2008). Dogs have also been shown to find and respond to different species of termites even when they were trained to only detect a certain species (Brooks, Oi & Koehler, 2003).

Dogs have also been shown to perform better than some detection technologies such as x-rays and thermal imaging cameras for detecting insect pests. In an experiment comparing the use of dogs with the use of other detection technology to find termites in timber, the detector dog was 100% effective while technology, such as x-rays performed less well (Zahid, et al., 2012). Hence detector dogs are one of the most accurate and effective tools to detect pest insects.

1.3 Dermestid Beetles

The Australian carpet beetle (*Anthrenocerus australis*) has been introduced to New Zealand and is now a pest of woollen carpets and fabrics in this country (Archibald & Chalmers, 1983; Gerard, 1994). It is from the Dermestid beetle family (Robertson, 1949; Archibald & Chalmers, 1983), which also includes the hide beetle (*Dermetes maculatus*), common carpet beetle (*Anthrenus scrophulariae*) and varied carpet beetle (*Anthrenus verbasci*). All three beetles can also be found in New Zealand (Archibald & Chalmers, 1983). These species have spread all over the world mainly in the holds of cargo ships, air freighters and even through parcel post (Hangay & Zborowski, 2010).

The Australian carpet beetle, as the name implies, is native to Australia (Gerard, 1994; Rees, 2004). The first reported incident of Australian carpet beetle infestation in New Zealand was in 1948 (Robertson, 1949). The adults are 2.2-2.5mm long, oval, black with light patches and are covered with light coloured hair running in a ‘zigzag pattern’ (Ferro, 1976; Rees, 2004). In nature, the larvae of the Australian carpet beetles are scavengers of material mainly of organic origin. Adults are normally found feeding on flowers (Rees, 2004). They can also be found in nests of birds, rodents, bees and ants (Rees, 2004).

Figure 1.1 Carpet that has been attacked by carpet beetles. Photo: Chloe Phoon

The eggs are laid in the infested material and the larvae feed and burrow into it (Rees, 2004). The larvae are elongated with long hairs extending from the end of the body (Ferro, 1976). The destructive stage of these insects is the larval stage (Robertson, 1949; Rees, 2004). It can take a year or longer for the larvae to reach adulthood depending on what they feed on (Rees, 2004). The larvae of these beetles have proven difficult to find because they live under carpets, especially carpets under furniture. Infestations are usually spotted by accumulations of cast larval skins, however, this is only obvious upon closer inspection of the carpet when infestations are severe (Rees, 2004).

These insects are also stored product pests and household pests. The larvae feed on stored products such as cereals, cured meat, biscuits, and peanuts (Rees, 2004, Hangay & Zborowski, 2010). They do major damage to woollen carpets and textiles (Robertson, 1949; Scholler et al., 1997; Rees, 2004, Hangay & Zborowski, 2010). The larvae which live under the carpet chew through the fibres causing the upper fibres to come loose (Ferro, 1976)

(Figure 1.1). They also cause major damage to museum artifacts of organic origin (Su & Scheffrahn, 1990; Linnie & Keatinge, 2000; Rees, 2004, Hangay & Zborowski, 2010). They may also cause asthma due to an allergen from larvae found in house dust (Cuesta-Herranz et al., 1997).

These beetles are not easy to control due to several factors. First, they breed in areas that are difficult to reach, and infestation may not be initially apparent (Ferro, 1976). As household pests they cannot conveniently be subjected to large scale fumigation because of the health hazard it may cause (Robertson, 1949). They attack fabrics that may be susceptible to damage by insecticide sprays having an oil or kerosene base and attack clothing which cannot be treated with insecticide sprays because of skin irritation (Robertson, 1949; Ferro, 1976). Due to health and safety considerations, the use of chemicals, which was the traditional method, is now discouraged for the prevention and treatment for museum pests (Linnie & Keatinge, 1999).

The inability to detect infestations quickly can lead to excessive usage of pesticides which is harmful to the environment, people and pets. Some of the problems with using chemicals are the development of resistance, environmental contamination and detrimental effects on human health (Barfield & Swisher, 1994; Thomas, 1999). The use of detector dogs can help with earlier discovery and identification of infested areas and thus reduce the use of pesticides. Early detection can reduce the damage, and preventive methods such as vacuuming can be applied rather than chemicals.

1.4 Thesis Structure

This thesis contains six chapters, an introduction (Chapter 1), a literature review (Chapter 2), materials and methods (Chapter 3), results (Chapter 4), discussion (Chapter 5) and references. The literature review covers the temperament of the dog, anatomy of the dog's nose, the theory of learning, and dog training methods. The materials and methods (Chapter 3) outlines the training and experimental model used in the present study. The results present the data for each of the experiments. The discussion explores the overall findings of the four experiments described below and their wider implications. It also discusses the limitations of the chosen methods.

The first experiment investigated the capability of harrier hounds to locate and indicate by sitting at the location of dog food. These dogs did not have prior scent detection training and therefore this experiment was done to determine whether these dogs were capable of detecting and responding to scent. This experiment was done to evaluate the appropriateness of the experimental model before testing whether dogs could detect carpet beetles and to develop the training techniques to be used in the next phase. Dog food was chosen because it was attractive to the dogs and had a strong smell. This experiment was done to develop techniques prior to other scent training trials.

The second experiment looked at whether the same dogs could detect Australian carpet beetle larvae (*Anthrenocerus australis*) in the same experimental model. Larvae were considered most appropriate because they are the destructive stage and it would be most useful to have dogs that could detect them in the field.

The third experiment was done using American cockroaches (*Periplaneta americana*) as the target because the dogs were unsuccessful in detecting the carpet beetle larvae. Cockroaches were chosen because they are also a household insect pest in New Zealand and because they have a strong smell. This experiment looked at whether these dogs could find and indicate an insect in the model, a stimulus which was not attractive to them but had a distinctive smell.

The final experiment used dog food as the stimulus again, however, the dog food used was different from the first experiment. This experiment aimed to see if the dogs would still succeed in finding an attractive olfactory stimulus in the experimental model. Thus the final two experiments helped us determine the reasons for the dogs' failure to successfully detect the carpet beetle.

Chapter 2

Literature Review

Royal. Photo: Chloe Phoon

2.1 Introduction

This literature review covers information on the domestication of dogs; their temperament and personality; the anatomy and physiology of the dog's nose; the theory of learning and dog training methods.

2.2 Domestication

Dogs (*Canis familiaris*) have lived with humans for 14,000 to 20,000 years (Morey, 1994; Nowak, 1999). Geneticists have shown that the progenitor of dogs were wolves (Vilà et al., 1997; Leonard et al., 2002; Pollinger et al., 2010). Domestication is a process in which an animal adapts to humans and the environment they provide (Price, 1999; Inoue-Murayama, Kawamura & Weiss, 2011). Adaptation is achieved through genetic changes occurring over generations (Price, 1999). There are several theories relating to the domestication of dogs (Miklósi, 2007):

- Individual based selection (Paxton, 2000): humans chose wolf cubs from the den that showed the "right" temperaments
- Population-based selection/ Dog-human symbiosis (Morey, 1994; Coppinger & Coppinger, 2001): an existing wolf population exploited a novel niche provided by humans
- Dog-human co-evolution (Paxton, 2000): wolves and humans changed in both function and morphology as a result of interacting with one another
- Cultural-technological evolution (Morey & Aaris-Sørensen, 2002): wolves were first used as work aids (or as a food source) and diversification happened when humans found ways to use dogs for different tasks such as hunting and guarding.

Out of all these theories, population-based selection theory is the most recognized and agreed upon. This theory suggests that domestication was not deliberate, rather wolves evolved through selection pressures to fit a new niche which was to live with humans (Morey, 1994; Coppinger & Coppinger, 2001).

Since then the dog has undergone morphological and behavioural changes through artificial selection which has led to the wide variety of dogs we have today (Hare, Williamson &

Tomasello, 2002; Gosling, Kwan & John, 2003; Akey et al., 2010). Each breed of dog is bred and trained to do different tasks. Within a breed, individual dogs vary in their performance (Helton, 2009). Some breeds are physically faster, while others are more accurate in sight or scent detection. Trained dogs have become useful and essential tools in many occupational settings. These include disability assistance (Lane, McNicholas & Collis, 1998; Davis et al., 2004), search and rescue (Fenton, 1992; Lasseter et al., 2003) and detection of illegal or dangerous substances (Phelan, 2002; Gazit &Terkel, 2003; Lorenzo, et al., 2003).

2.3 Temperament and Personality

2.3.1 Definition

Studies have shown that animals have personality (Gosling & John, 1999; Bouchard & Loehlin, 2001). There is no single definition for temperament and personality in non-human animals (Gosling, 2008; Inoue-Murayama, Kawamura & Weiss, 2011). Temperament is preferred over personality, as personality is associated with humans. Fratkin et al. (2013) defined temperament as 'correlated suites of behaviour' while Inoue-Murayama, Kawamura & Weiss (2011) defined temperament as "an individual's distinctive pattern of behaviour that is consistent across time and situations."

Temperament has been reported and measured in many animals including octopuses (Mather & Andersson, 1993), fishes (Wilson et al., 1993), cats (Feaver et al., 1986), and primates (Stevenson-Hinde et al., 1980). Ivan Pavlov was one of the first scientists to study dog personality and classified dogs into four basic personality types (excitable, lively, quiet and inhibited) through their responses to conditioned reflex training (Pavlov, 1941). Since then, research on this topic has flourished.

2.3.2 Genetics and Temperament

Breeds are "intraspecies groups that have relatively uniform physical characteristics developed under controlled conditions" by humans (Irion et al., 2003). The entire dog genome was sequenced in 2003 and published in 2006 (Boyko, 2011). When dog breeds were compared, scientist found that there was about 30% of genetic variation which is considered high compared to the genetic differentiation found among the human population which is in the range of 5 to 10% (Parker et al., 2004; Lindblad-Toh et al., 2005; Saetre et al. 2006; Inoue-Murayama, Kawamura & Weiss, 2011). This genetic variance contributes to the large number of dog breeds. There are currently about 400 breeds of dogs each with different morphology and behaviour (Parker et al., 2004). Genes influence morphology, physiology, learning, memory and cognition (Breed & Sanchez, 2012).

Studies have been done on the association of genes and behavioural traits/temperament. Genes affect neurotransmitters which are known to affect temperament, and influence physiology and morphology. Some genes seem to be directly related to certain behaviours (Scott & Fuller, 1965). Niimi et al. (1999, 2001) found seven length-variant polymorphisms in the *DRD4* exons in three dogs. It is thought that these gene variations are associated with behavioural traits such as excitability, aggression, reactivity and novelty seeking (Ebstein et al., 1997; Niimi et al., 1999). Other studies reported a weak association between the distractibility trait and a *5HTT* haplotype in Labrador Retrievers trained to detect drugs (Maejima et al., 2007). There was also a significant association between a TH intron 4 polymorphism and the activity-impulsive trait in German Shepherds (Vas et al., 2009). It is also interesting to note that aggression was higher in breeds with higher frequency of long alleles than those with more short alleles (Maejima et al., 2007).

Genes may also play a part in cognitive ability such as trainability, however, the research is not conclusive (Hart, 1995; Rooney & Bradshaw, 2004; Serpell & Hsu, 2005; Maejima et al., 2007). Though the research is still unclear about the influence of genes on trainability, the desire for work or a “work drive” is necessary in training for work (Wilsson & Sundgren, 1997; Rooney & Bradshaw, 2004; Maejima et al., 2007).

Genes determine the morphology of dogs and this affects the efficiency and ability to complete specific tasks. It is obvious that dogs with longer legs have longer strides and therefore would run faster than dogs with short legs. Racing dogs cannot have too large a body because it retains too much heat, or too small a body because it retains too little heat (Coppinger & Coppinger, 2001). Pit bulls are built for gripping and fighting, whereas Greyhounds are built for sprinting (Kemp et al., 2005). Dogs with longer noses had more visual streaks which is the area of highest acuity in the retina (Evans & McGreevy, 2007).

Dogs such as the greyhound are very sensitive to movements as visual streaks facilitate better resolution vision in the periphery, which makes them good sight hunters.

Some genes are inherited and can shape behaviour and temperament (Breed & Sanchez, 2012). Saetre et al. (2006) looked at the heritability of certain behaviours in German shepherd and Rottweiler dogs. The heritability of boldness was estimated to be 0.25 in the two breeds which exceeded other behavioural traits such as play, sociability and curiosity (0.04-0.19). Other studies have found certain behavioural traits to be consistent in dog breeds which suggest high heritability (Boake 1989; Hayes & Jenkins, 1997; Svartbeg et al., 2005).

2.3.3 Methods for Assessing Temperament

There are four main methods used to assess temperament in dogs: (1) test batteries, (2) observational tests, (3) ratings of individual dogs, and (4) expert ratings of breed prototypes (Jones & Gosling, 2005).

- Test batteries involve recording the reaction of a dog to a range of specific stimuli. It is the most common method used.
- Observational tests assess a dog in a natural environment unlike test batteries in which the tests are run in a controlled environment.
- Ratings of individual dogs gather information about a dog indirectly through informants such as dog owners.
- Expert ratings of breed prototypes also collect data through informants, however, in this case the informants were deemed to be experts on dogs (e.g. dog trainers, vets).

Each of these methods can be used to measure and assess a variety of temperaments such as fearfulness, sociability, responsiveness, aggressiveness and activity.

- Fearfulness is one of the most studied traits (Reuterwall & Ryman, 1973; Goddard & Beilharz, 1984; Wilsson & Sundgren, 1997, 1998). It is sometimes labelled as apprehension and timidity (Cattell & Korth, 1973; Hennessy et al., 2001).

- Sociability is the initiation of friendly interactions with people and other dogs (Reuterwall & Ryman, 1973; Hart, 1995; Gosling, Kwan & John, 2003; Fallani et al., 2006).
- Responsiveness to training is the ability to learn and work with people and the overall reaction to the environment (Cattell & Korth, 1973; Goddard & Beilharz, 1983; Maejima et al., 2007).
- Aggression was assessed through behaviours such as biting, growling, and snapping at people or other dogs (Reuterwall & Ryman, 1973; Wilsson & Sundgren, 1997).
- Activity was used for traits including social and individual play as well as locomotion (Cattell & Korth, 1973; Reuterwall & Ryman, 1973; Fallani et al., 2006).

However, most studies have narrowed the dog's personality to 5 main traits: playfulness, curiosity/fearlessness, chase-proness, sociability and aggressiveness (Svartberg & Forkman, 2002; Svartberg, 2005; Ley, Bennett & Coleman, 2007).

Each of these temperaments can also be measured on an axis. The shyness-boldness continuum is an axis of behavioural variation used in animals to quantify an individual's tendency to take a risk (Wilson et al., 1994). Other axes include the proactive-reactive axis (Koolhass et al., 1999), individual differences in aggressiveness (Benus et al., 1991; Wilsson & Sundgren, 1997), neophobia (Cavigelli & McClintock, 2003; Keltikangas-Jarvinen et al. 2004) and exploratory behaviour (Verbeek et al., 1994).

Factors such as age can influence the outcome when assessing temperament. Older dogs have a more consistent personality compared to puppies and puppy personality tests may not be a reliable method for assessing the temperament of a dog (Wilsson & Sundgren, 1998; Jones & Gosling, 2005; Svartberg, 2005). In puppies, temperament traits such as responsiveness to training and fearfulness were found to be completely unreliable and changed as the puppy grew up (Fratkin et al., 2013). It is therefore recommended to assess temperament in young dogs, about 1-2 years of age (Wilsson & Sundgren, 1998).

Sex and the sexual status of a dog may also influence temperament (Svartberg, 2002). Some studies showed that males were more prone to show aggressive behaviour and males that were not castrated to be even more aggressive (Podberscek & Serpell, 1996; Roll & Unshelm, 1997). Females that were intact were also more likely to show aggressive behaviour than neutered females (Podberscek & Serpell, 1996; Roll & Unshelm, 1997). Males had a higher prey and defence drive compared to females (Wilsson & Sundgren, 1997)

2.3.4 Temperaments in Working Dogs

Temperament can determine the effectiveness of a working dog (Svartberg, 2002; Maejima et al., 2007). There are a few main traits that will determine the success of a dog. Svartberg (2002) found that the shyness-boldness continuum is valid for working dogs; there is a positive correlation between boldness and the success of a working dog. The desire to work is an important trait in any working dog. Maejima et al. (2007) found that 93.3% of dogs scoring high on desire for work were successful in a detection test, compared to dogs that had a low desire to work (53.3%). Guide dogs are usually rejected due to behavioural issues such as fearfulness and aggressiveness rather than their physical abilities (Goddard & Beilharz, 1983; Weiss & Greenberg, 1997; Serpell & Hsu, 2001).

There are differences in behaviour and temperament between breeds. English Springer Spaniels and Border Collies were found to be better at locating explosives, weapons or drugs than Labrador Retrievers as they scored higher at agility, independence, stamina and motivation to obtain food (Rooney & Bradshaw, 2004). Mahut (1958) found that rat hunting breeds such as terriers were less fearful compared to bird hunting and herding breeds. German shepherds, which are mostly used as police and protection dogs, scored higher for acuity and precision but even more for defence drive than Labrador retrievers. Labrador retrievers scored higher for nerve stability, reacted less strongly to gunfire and were more cooperative than German shepherds. These differences make Labrador retrievers more suitable as guide dogs, compared to German shepherds (Wilsson & Sundgren, 1997).

2.3.5 Other Uses of Temperament in Animals

There are other reasons to study animal temperament. Technological advances have allowed scientist to remove and insert genes or manipulate hormone levels. These manipulations allow us to study the relationship between hormones, biological processes, and behaviour (Gosling, 2008). Animal-temperament research can also increase our understanding of the effects of personality traits on health outcomes. A study done by

Capitanio et al. (1999) found that the sociability of a rhesus monkey can predict both behavioural responses and the antibody response to simian immunodeficiency virus (SIV) disease inoculation, which would influence survival. Animal welfare and management are also areas in which animal temperament studies are of use, for example, managing temperament types may decrease stress in zoo animals (McDougall et al., 2006; Watters & Meehan, 2007).

2.4 Anatomy & Physiology

One of the main reasons dogs are so useful is because of their good sense of smell (Olender et al., 2004; Quignon et al., 2012). Dogs have up to 100 times more scent receptors than humans (Zink, 2004; Quignon et al., 2012). This allows them to detect almost any scent, from humans to minute amounts of chemicals (Phelan, 2002; Lasseter et al., 2003; Singh, 2007). Puppies are deaf and blind till about 2-4 weeks of age, however olfaction becomes functional between 8 to 13 days after birth (Lord, 2013).

2.4.1 Anatomy of a Dog's Nose

There are several physical characteristics that make dogs such excellent detectors. Dogs have turbinate bones that are folded to increase surface area (Schreider & Raabe, 1981; Pihlström et al., 2005). The olfactory receptor epithelium lines one of the turbinate bones called the ethmoid turbinate. The olfactory receptor neurons located in this epithelium have cilia bathed in mucus, over which the stimuli flow (Rebmann, David & Sorg, 2000; Helton, 2009). The olfactory epithelium of a dog is approximately 170 cm^2 in size compared to the human's 10 cm^2 and is more densely packed with olfactory receptor neurons per unit area (Helton, 2009).

Air molecules pass over the olfactory receptor epithelium and bond to the olfactory receptors which then send signals to the olfactory bulb. This signal is then sent to the appropriate parts to the cortex to be processed (Rebmann, David & Sorg, 2000; Goldblatt, 2009). In the cortex, there are two types of neural connections, the first type is the primary recognition of the odour (which is the main olfactory system and accessory olfactory system) and the second type deals with the emotional functions associated with the odour (Rebmann, David & Sorg, 2000; Quignon, et al., 2012).

2.4.2 Sniffing

Steen et al. (1996) found that while searching for a ground scent, their dogs sniffed at a frequency of up to 200 times per minute, a strategy which may create turbulence in the nasal passage and thereby enhance transport of scent molecules to the receptors in the ethomoidal cavity. Sniffing is the action that gets the odour from the air into the nose of the dog. This action has many functions during olfaction (Kepecs, Uchida & Mainen, 2006). First, the sniffing action disturbs the ground and raises the odours (Helton, 2009). Second, sniffing draws in greater amounts of air and creates a unique nasal airflow pattern which is optimized for odorant transport over the olfactory mucosa (Rebmann, David & Sorg, 2000; Craven, Paterson & Settles, 2009). Third, the humidity and heat from sniffing facilitates the absorption of odorant molecules into the mucosa (Helton, 2009; Scott, 2006). Lastly, it has been found that in sniffing and regular breathing air follows different pathways. Sniffing diverts air into a path over the olfactory epithelium while regular breathing diverts air straight to the lungs (Helton, 2009; Craven et al., 2007; Scott, 2006).

2.4.3 Odorant Receptors (OR)

Odorant receptors (OR) were first discovered by Buck and Axel (1991) and are specific receptors that capture the odorant molecules. The olfactory mucosa contains the olfactory epithelium which contains the neurons expressing odorants receptors (Quignon et al., 2012; Galibert, 2009). Odorant receptors are encoded by OR genes, of which a dog has up to 1,300 compared to the human's 650 (Quignon, et al., 2003; Quignon et al., 2005). It is this diversity, as well as polymorphism that contributes to the wider range of detected molecules in a dog. Two studies found that there was a high level of polymorphism in German Shepherds and Labrador Retrievers (which are commonly used in scent detection) compared to Pekingese dogs and Greyhounds (Robin et al., 2009; Galibert, 2009). This suggests that German Shepherds and Labrador Retrievers have a wider range of scent detection.

2.5 Theory of Learning

The theory of learning describes the ways in which animals learn. It can be described using a number of categories including habituation, observational learning, imprinting, insight learning and conditioning. There are two types of conditioning: operant conditioning, also called instrumental conditioning, and classical conditioning (Schlegl-Kofler, 2008; Mazur, 2014).

2.5.1 Habituation

Habituation is the most primitive form of learning. It is defined as "a decrease in strength of a response after repeated presentation of a stimulus that elicits the response" (Mazur, 2014). Any elicited response can exhibit habituation which is most evident in the body's automatic response to new and sudden stimuli (Mazur, 2014). A study done by Dielenberg and McGregor (1999) showed how animals can habituate to fear provoking stimulus if the stimulus repeatedly proves to be insignificant. Habituation allows an individual to ignore the many insignificant stimuli it encounters repeatedly in life and to focus on more important issues (Mazur, 2014).

2.5.2 Imprinting

Imprinting is the ability to learn an essential piece of information at the right stage of development, which usually happens during the neonatal period (Salzen, 1967; Immelmann, 1975; Breed & Sanchez, 2012). There four main criteria characteristics of imprinting: (1) It can take place only during a restricted time period of the individual's life, the sensitive period (or critical period); (2) it is irreversible, that is, it cannot be forgotten; (3) it involves learning characters such as beak colour that is specific to that species and; (4) it may be completed at a time when the appropriate reaction itself is not yet performed (Salzen, 1967).

Imprinting is important in many areas of a young animal's life. It is important for infant-mother relations (Salzen, 1967; Moore, 2004), food preference (Hepper & Wells, 2006), sexual preference (Vos, 1995) and habitat preferences (Davis & Stamps, 2004). Sexual imprinting has been studied in detail in precocial birds (Immelmann, 1975; Moore, 2004). It is a process whereby mate preferences by individuals are learned through exposure, usually using the parents as a model (Irwin & Price, 1999; Todd, 1993). Vos (1995) found that male zebra finches, *Taeniopygia guttata*, clearly showed a preference for birds with the same bill colour as their mother. A study done on puppies about chemosensory stimuli showed that when puppies were exposed to aniseed (prenatal via the dam and postnatal via the puppy), they significantly preferred aniseed flavoured food than the other types (Hepper & Wells, 2006). This may be advantageous in acquiring information about "safe" foods after weaning (Hepper & Wells, 2006).

2.5.3 Insight Learning

Insight is the ability to solve a problem not through trial and error or observing someone else attempt the problem. It is an abrupt realization of the solution and a completely cognitive experience (Heinrich, 1995; Lind & Enquist, 2012). There are four characteristics in insightful learning: (1) the transition from presolution to solution is sudden and complete; (2) performance based on a solution gained from insight is sudden and free of errors; (3) a solution to a problem gained by insight is retained for a considerable length of time; (4) a principle gained by insight is easily applied to other problems (Olson & Hergenhahn, 2009). However, demonstrating insight in animals is difficult because it is currently not known how different a test situation must be for shaping or operant conditioning to be excluded as explanations (Lind & Enquist, 2012). Birds such as the Common raven (*Corvus corax*), are known for solving problem through insight. Heinrich (1995) found that results varied between individuals when he presented them with a string-pulling problem. Some were able to get it on the first try while others required many attempts.

Two studies compared the ability of dogs and wolves to solve certain tasks. Both studies showed that adult dogs and juvenile wolves required more trials to learn a task compared to adult wolves (Frank et al., 1989; Hiestand, 2011). They concluded that wolves exhibit more insight than dogs and are able to solve problems on their own. Interestingly, Topál, Miklósi & Csányi (1997) said that this might be due to a dog's strong relationship with humans. Dogs in a companion relationship behaved in a way suggesting that they were socially dependent, showing a decreased performance in problem solving tasks.

2.5.4 Observational Learning

Learning may occur through observation (Mazur, 2014). This can be categorised into imitation and emulation. Imitation is "learning something about the form of behaviour through observing others" (Heyes, 1993). The subject must recognize the goal of the behaviour. This is hard to prove in animals. Emulation happens when the subject recognises the problem and develops his or her own technique to solve it (Helton, 2009).

Slabert and Rasa (1997) found that German shepherd puppies that were present when their mothers routinely participated in drug retrieval trials performed these tasks more easily than puppies without this experience. Pongrácz et al. (2001, 2003) found that dogs performed better at a detour test when there was a human demonstrator. Owners and strangers were equally effective demonstrators. The ability of a dog to learn from a demonstrator depends on its dominance. Dominant rank dogs learn well from unfamiliar human demonstrators but fail to learn anything from unfamiliar dogs. Subordinate dogs learn almost equally well from both dog and human demonstrators (Pongrácz et al., 2007).

Social learning is a type of observational learning but, it is rarely used in training dogs (Helton, 2009). The social learning theory is “a combination of (1) the traditional principles of classical and operant conditioning, plus (2) the principles of observational learning, or imitation” (Mazur, 2014).

2.5.5 Classical Conditioning

Classical conditioning involves an animal’s innate reflexes (Mazur, 2014). It is a process of behaviour modification in which an innate response to a stimulus becomes expressed in response to a previously neutral stimulus (Dickinson & Mackintosh, 1978)

The standard paradigm of classical conditioning is as follows (Dickinson & Mackintosh, 1978; Mazur, 2014) (Figure 2.1):

- A stimulus called the unconditioned stimulus (US) evokes a response called the unconditioned response (UR). The term unconditioned is used to indicate that the connection between the stimulus and response is unlearned (innate).
- The second element of the classical conditioning paradigm is the conditioned stimulus (CS), which can be any stimulus that does not initially evoke the UR. The term conditioned stimulus indicates that it is only after conditioning has taken place that the CS will elicit the response.
- Any response following the CS is referred to as a conditioned response (CR).

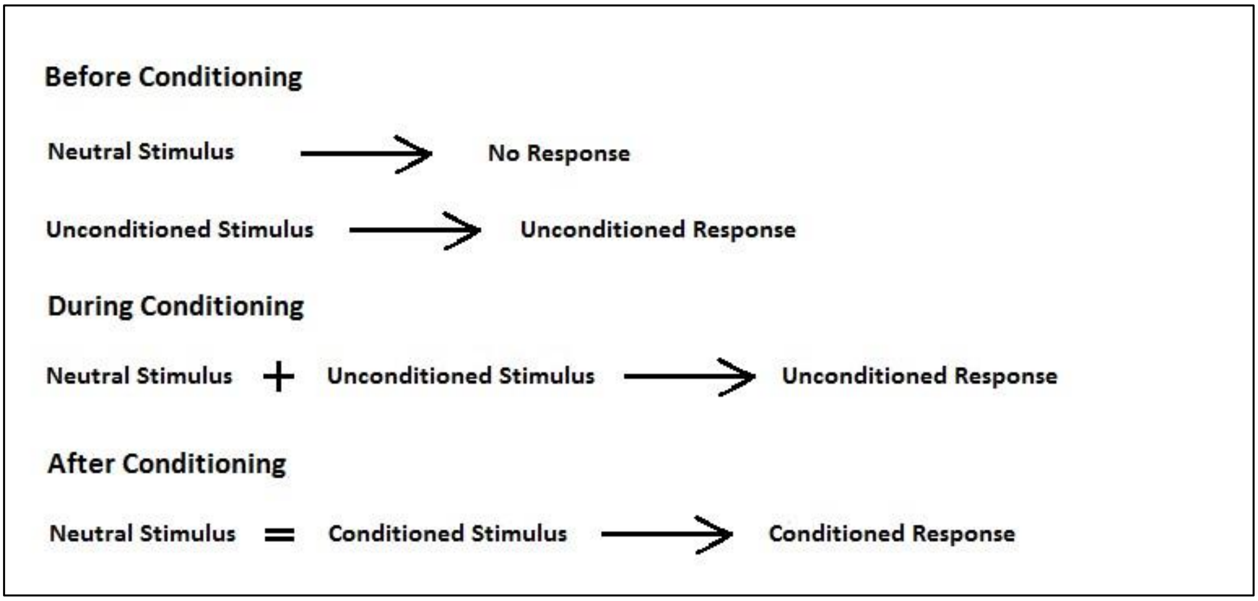


Figure 2.1 Classical (Pavlovian) conditioning. Source: Mazur (2014)

The best known examples of classical conditioning are the experiments done by Pavlov on dogs. Pavlov was interested in the secretion of saliva and used dogs as his subjects. He used food (US) to stimulate salivation (UR) in dogs (Figure 2.1). However, he noticed that unlike a new subject, an experienced dog (one that had been through the testing procedure a few times) would begin to salivate even before the food was presented. Pavlov realized that some stimulus (a bell) preceding the presentation of food elicited the response of salivation (Schlegl-Kofler, 2008; Mazur, 2014). Since then, various animals have been trained using classical conditioning including: rats (Wilker & Pescor, 1967), wombats (Swinbourne, 2014), coyotes (Gustavson, 1974) and Aplysia (a genus of sea slugs) (Hawkins, 1983).

2.5.6 Operant Conditioning

Operant conditioning, also known as instrumental conditioning, is "learning from the consequences of our behaviour" (Brembs, 2003). Is it a process in which a behaviour is strengthened through reinforcement, but is also a process in which behaviour. It is unlike classical conditioning which is limited to involuntary behaviours (Mazur, 2014). The frequency of reinforcement is dependent on the subject's behaviour, that is, no reinforcement will occur until the subject makes the required response (Mazur, 2014). Operant conditioning is the most commonly used type of learning in dog training (Rebmann, David & Song, 2000; Schlegl-Kofler, 2008). The subject learns through success or failure.

2.5.7 Reinforcement and Punishment

In operant conditioning there are four possible relationships/consequence for a behaviour. (Schlegl-Kofler, 2008; Mazur, 2014): Positive reinforcement, negative reinforcement, positive punishment and negative punishment.

Positive and negative reinforcement

Positive reinforcement occurs when a behaviour is followed by a reinforcer and the behaviour is strengthened (Schlegl-Kofler, 2008; Mazur, 2014). A positive reinforcer is something a subject wants, such as food, petting or praise (Pryor, 1999; Schlegl-Kofler, 2008). Positive reinforcement is favoured because it develops a better relationship between trainer and dog (Rooney & Cowan, 2011).

The reinforcer is a stimulus that increases the expression of a desired behaviour (Mazur, 2014). A primary reinforcer is a stimulus that naturally strengthens any behaviour when it is presented. Primary reinforcers include food, water and comfort (Mazur, 2014). Secondary reinforcers, also known as conditioned reinforcers, are previously neutral stimuli but have the ability to strengthen a behaviour when paired with a primary reinforcer (Pryor, 1999, 2005; Mazur, 2014). After repeated pairing with the primary reinforcer, the conditioned reinforcer can act as a substitute for the primary reinforcer. An example is a dog associating the sound of a clicker with obtaining a treat (Pryor, 1999, 2005).

Negative reinforcement occurs when a behaviour increases in frequency if the reinforcer is removed after the behaviour occurs (Iwata, 1987; Mazur, 2014). This also includes avoidance in which a response prevents an unpleasant stimulus from occurring in the first place. A negative reinforcer is something the subject wants to avoid, such as a blow, a frown or an unpleasant sound (Pryor, 1999; Schlegl-Kofler, 2008). The dog employs a certain behaviour to escape an unpleasant feeling (Iwata, 1987; Schlegl-Kofler, 2008). There are three features in a negative reinforcement paradigm: the presence of aversive stimulation, the availability of a response, and a suitable contingency between the response and the stimulation (Iwata, 1987). Solomon and Wynne (1953) conducted an experiment that illustrates many of the properties of negative reinforcement. This involved shocking a dog with an electric shock 10 seconds after lights were switched off. The dog could jump over a barrier to escape. After a few trials, the dogs would jump over the barrier 2-3 seconds after the lights were switched off.

Reinforcement schedules

A reinforcement schedule is a rule that states under what conditions and when a reinforcer will be delivered (Staddon, Wynne & Higa, 1991; Mazur, 2014). There are four simple reinforcement schedules: fixed ratio, variable ratio, fixed interval and variable interval (Staddon, Wynne & Higa, 1991; Mazur, 2014). Other reinforcement schedules include continuous reinforcement schedule, differential reinforcement of low rates (DRL) schedule, differential reinforcement of high rates (DRH) schedule, progressive schedule and chained schedules (Mazur, 2014).

The rule for a fixed-ratio (FR) schedule is that a reinforcer is delivered after every *n* response, when *n* is the size of the ratio. For example, in a FR 10 schedule, every 10 responses will be followed by a reinforcer. A FR 1 schedule is the same as a continuous reinforcement (Mazur, 2014). A variable ratio (VR) schedule is one in which a subject will receive one reinforcer for every *n* responses. However, the exact number of responses required at any moment may vary (Mazur, 2014).

In interval schedules, the presentation of a reinforcer depends both on the subject's behaviour and on the passage of time. The rule for a fixed-interval (FI) schedule is that the first response after a fixed amount of time has elapsed is reinforced. For example, in an FI 30-second schedule, immediately after one reinforcer has been delivered, a clock starts to time the next 30-second interval (Mazur, 2014). Variable intervals (VI) schedules are like FI schedules except the amount of time that must pass varies unpredictably from reinforcer to reinforcer (Mazur, 2014).

One of the factors that affects the success of a reinforcement schedule is the timing of the reinforcer (Mazur, 1995; Mazur, 2014). Idealistically, the reinforcer should be presented immediately after the behaviour occurs. A reinforcer's effectiveness decreases as the delay between response and reinforcer increases (Mazur, 1995; Mazur, 1997; Yamamoto, Kikusui

& Ohta, 2009). Warren-Smith et al., (2012) conducted a study using negative reinforcement to teach foals to walk forward. Pressure applied to a headcollar via a lead rope was used as the stimulus for each foal to walk forward, and this was repeated until the foal had walked a distance of 8 m. Foals appeared to learn more quickly when pressure was released after the first foreleg step commenced compared to when the second or fourth step was completed. Timing and consistency is important during training. The subject can become confused when there is inconsistency and variable timing which can impair learning (McGreevy & McLean, 2009; Yamamoto, Kikusui & Ohta, 2009).

The type of reinforcer can also affect the individual's ability to learn. Some individuals respond to food rewards, while others may respond better to play rewards (such as tug-of-war). Dogs with a high play drive will want to retrieve or tug with a human (Cablk & Heaton, 2006). A high play drive is one of the desired characteristics in a detection dog (Wasser et al., 2004; Cablk & Heaton, 2006). The dog is motivated by the anticipated reward of a play object. Tactile stimulation has also been used as positive reinforcers. This includes patting, stroking and grooming (Fonberg & Kostarczyk, 1980; Taira & Rolls, 1995; Haverbeke, et al., 2008). A study done on primates showed that it is the orbital part of the prefrontal cortex that is involved in reinforcement preferences (Tremblay & Schultz, 1999).

There are many examples of positive reinforcement used in the training of animals. Positive reinforcement training (PRT) has been used to train non-human primates in laboratory settings to cooperate with routine scientific, husbandry and veterinary procedures (Bloomsmith, Stone & Laule, 1998; Schapiro, Pearlman & Boudreau, 2001; Schapiro, Bloomsmith & Laule, 2003). PRT allows the subjects to cooperate voluntarily with the procedures, reducing stress and aggressive behaviour (Schapiro, Bloomsmith & Laule, 2003). Pandas have been trained to move from one enclosure to another using PRT (Bloomsmith, et al., 2003). Dogs are a prime example of the success of PRT. PRT has been used to curb excessive barking, jumping and crowding when people arrive at the door (Yin, et al., 2008). Working dogs are trained to complete various task using both positive and negative reinforcement (Marschark & Baenninger, 2002; Haverbeke, et al., 2008).

Conditioned reinforcement: Clicker training

A conditioned reinforcer can act as a substitute for a primary reinforcer, increasing the strength of any response that it follows (Mazur, 2014). A conditioned reinforcer is a meaningless signal such as a sound, a light or a motion that is presented before or during the delivery of a reinforcer (Pryor, 1999, 2005). A clicker is the most common conditioned reinforcer used to train dogs (Pryor, 1999, 2005). This has revolutionized the way animals are trained, especially with animals (such as dolphins and birds) that cannot be trained through aversive positive punishment.

Before the clicker can be used, the dog must learn the meaning of the clicker. This is done by clicking the clicker and then giving a treat to the dog (Pryor, 1999, 2005). After doing this several times, click and delay the treat for a few seconds. If the dog actively searches for a treat during the waiting period, the signal has become a conditioned reinforce (Pryor, 1999, 2005). It becomes a bridge between earning the food and getting the food. There have been many success stories using clicker training. These include dogs learning to detect landmines with 95% detection reliability after 15 weeks (Fjellanger, Anderson & McLean, 2002) and squirrel monkeys mastering various complex task within two weeks (Gillis, Janes & Kaufman, 2012)

An advantage in using the clicker is the ability to deliver the signal reinforcer at the very exact moment of a certain behaviour (Pryor, 1999, 2005; Rebmann, David & Sorg, 2000). The conditioned reinforcer offers the trainer a way to communicate precisely to the dog. Another advantage in using a conditioned reinforcer is the ability to reinforce a behaviour at a distance even if the animal is not facing the trainer (Pryor, 1999, 2005). When food is the primary reinforcer without a conditioned reinforcer, the animal will always be looking at the trainer for approval or a reward (Pryor, 1999, 2005). This reduces unwanted requests for food in the early stages of training (Waran, McGreevy & Casey, 2007). Using a conditioned reinforcer should decrease learning and training time (Waran, McGreevy & Casey, 2007). However studies have shown that clicker training does not decrease training time compared to when only a primary reinforcement was used (Williams et al., 2004; Smith & Davis, 2008). Smith & Davis (2008) did however find that clicker training does increase resistance to a behaviour’s extinction. The sound of a clicker or a whistle is preferred over human praise because it is distinctive (Waran, McGreevy & Casey, 2007). Words can cause confusion especially since they are commonly used in any setting, including outside training sessions.

Positive and negative punishment

Positive punishment occurs when a behaviour is followed by an unpleasant stimulus (Mazur, 2014). Smacking, punching, kicking or a loud verbal “No” are examples of positive punishment. Negative punishment occurs when a pleasant stimulus (such as food) is removed or omitted to reduce the likelihood of a behaviour occurring (McGreevy & McLean, 2009; Mazur 2014). Even though punishment is less favoured in modern day training, punishment is still an effective way in training animals. Punishment is used commonly when a horse bites or kicks a human (McGreevy & McLean, 2009). It also effective when wanting to curb behaviours such as chewing household objects (Hiby, Rooney & Bradshaw, 2004).

The effectiveness of a punishment is influenced by a few factors. The most effective punishment is one that is delivered immediately after the undesired behaviour (McGreevy & McLean, 2009; Mazur, 2014). The manner in which a punishment is introduced can influence its effectiveness. All punishments must be introduced at a sufficient intensity as subjects can habituate to mild punishers (Melvin & Anson, 1969; Mazur, 2014). The subject’s motivation to respond also plays a big part. The effectiveness of a punishment procedure is inversely related to the intensity of the subject’s motivation to respond to the punishment (Azrin, Holz & Hake, 1978; Mazur, 2014).

Punishment can elicit several emotional effects such as fear and anger, which are generally disruptive of learning and performance (Schilder & van der Borg, 2004). It can lead to a general suppression of all behaviours, not only the behaviour being punished (Mazur, 2014). Punishment can also cause problematic behaviours such as aggression (Hiby, Rooney & Bradshaw, 2004). A dog is more willing to please a trainer when it enjoys its time learning compared to doing something out of fear (Schlegl-Kofler, 2008).

2.6 Training a Dog

Dogs can become very good at a task through deliberate training and practice. Dogs can be taught and trained by repeatedly performing the same actions over and over. They may not consciously know the purpose of the exercise and treat each problem as play (Spinka, Newberry & Bekoff, 2001). It is not known whether dogs engage in play deliberately to improve predatory skills, or if predatory object play and skill at predation of live prey seem to be connected (Caro, 1995; Helton, 2009). However studies have shown that play does not improve predatory or fighting behaviour (Caro, 1980; Sharpe, 2005).

There is no one way to train a dog. Each dog has its own temperament (Wilson et al., 1994) and is motivated in different ways (e.g. by food or toys) (Schlegl-Kofler, 2008). It is the ability of humans to exploit a dog's willingness to serve, the attraction to food and rewards and the close social bonds between dogs and people that makes it possible to train a dog (Helton, 2009).

2.6.1 Basic Obedience and Training

Any potential working dog must be taught basic obedience, which includes sit, down, come on command, heel and stay (American Rescue Dog Association, 2002; Schlegl-Kofler, 2008). These commands can be introduced to a puppy as early as eight weeks of age (American Rescue Dog Association, 2002). Socialization is also important at this stage as the puppy's brain is especially receptive to experiences and stimuli (Weiss & Greenberg, 1997). They should be exposed to different sights and sounds including different situations such as riding in a car, swimming, walking up stairs and unstable footing (American Rescue Dog Association, 2002). The attention span of a puppy is not very long, hence sessions should be short and exciting (American Rescue Dog Association, 2002). Puppies are not physically capable of strenuous activities for long periods.

2.6.2 Detection Training

Positive reinforcement and conditioned reinforcers (clicker) can be used to train a detector dog. There are many types of detector dogs. Some work in search and rescue while others work in border security.

Basic Scent Training

The first step to scent training is to introduce the target scent to the dog and reward it when it responds. This is operant conditioning using positive reinforcement. The dog learns to differentiate the scent from others and the response is strengthened through repetition.

The process for basic scent training is as follows (Rebmann, David & Sorg, 2000):

- Step 1 – Scent Introduction: start with a line of blocks with one of them having the target scent. With the dog on the leash, start down the line and if the dog stops and drops its nose at the target block, click and reward it immediately. If the dog does not respond the first time, start again at the first block and draw its attention to each of the blocks with your finger. Once the dog reaches the target block, reward it immediately. Always reward the dog as close to the source of scent as possible.
- Step 2 – Introduce the Command: Each search task should have a cue. This command will be used to cue the dog at the start of each exercise.
- Step 3 – Introduce the Trained Indication: the trained alert is the indication that the dog is trained to perform when it encounters the target odour. This can either be active (digging, barking) or passive (sitting). With the dog on the leash, give the cue and start along the line of blocks. Once the dog dips its head towards the target block, cue its trained indication. When it performs the trained indication, click and reward immediately.

This training can be done with any scent, whether it be cadavers, drugs, explosives or other animals. Besides basic scent detection training, each dog will have more specialized and advance training for each type of job.

Search Training

Search dogs, as their name implies, have to learn how to search. One of the first recorded utilization of dogs for search and rescue was in the 1700s. The monks at St. Bernard Hospice in Switzerland used search dogs to look for stranded travellers or their bodies in the mountain passes between Switzerland and Italy (Fenton, 1992). Search dogs are generally selected from working breeds of medium size, such as the Golden or Labrador Retrievers, German Shepherds or Border Collies (Fenton, 1992).

A search dog will need to be fit when searching for a person so that they can get to them as quickly as possible. Search training should also be done outdoors as search dogs will be working outside for most of the time. Search dogs are required to be agile as the terrain and environment can be variable and unstable. Most trainers prefer to start obedience training and agility training before 6 months of age (Alexander, Friend & Haug, 2011). Some of the equipment used to train agility include: ramps, metal pipes as tunnels, teeter-totters, ladders and 55-gallon oil drums (American Rescue Dog Association, 2002). An example of basic search training involves a person hiding while the dog looks for the person (Fenton, 1992; American Rescue Dog Association, 2002).

- Start by running ahead of the dog and once you have reached a far enough distance, flop down behind a clump of grass and wait for the dog to come looking for you. If he does not seem to be able to find you, make a sound or motion to attract it. Once he has found you, reward and praise him (this step can only be done with puppies as it is difficult to out run adult dogs).
- The next step requires an assistant. The assistant will restrain the dog while you run ahead and hide. The dog will still be able to see you in this step. The assistant should say "Find him" when she releases the dog.
- Over time, this exercise should increase in difficulty by using other people and searching for longer periods.
- The last step is asking the dog to search for a person without him seeing hide. If the dog has a problem looking the person, he make a sound or motion to attract it.

The dog should always succeed in finding the target person. Always remember to encourage the dog throughout the search and praise him when he accomplishes the task.

In order for a search dog to perform at its best the handler must be aware of how scent travels in an environment. Molecules from an object become more and more dispersed in the air as they move further away. This gradient forms a cone; this is called a scent cone (Rebmann, David & Sorg, 2000). Dogs are able to distinguish the pressure and relative concentration of scent and follow the pattern to the source. However, it is now recognized that odours do not disperse in a linear continuous gradient, but rather their dispersal is subject to turbulence, which creates a much more dynamic and complex odour stimulus (Murlis, Willis & Carde, 2000; Weisburg, 2000). There are a number of scent cone distortions that need to be understood by the handler during a search (Rebmann, David & Sorg, 2000). For example, wind or water flow can be altered by scent barriers, which may cause the formation of scent pools which could potentially form a new secondary scent cone. Handlers must be aware of these distortions so that the dog does not get confused.

Multiple scent training

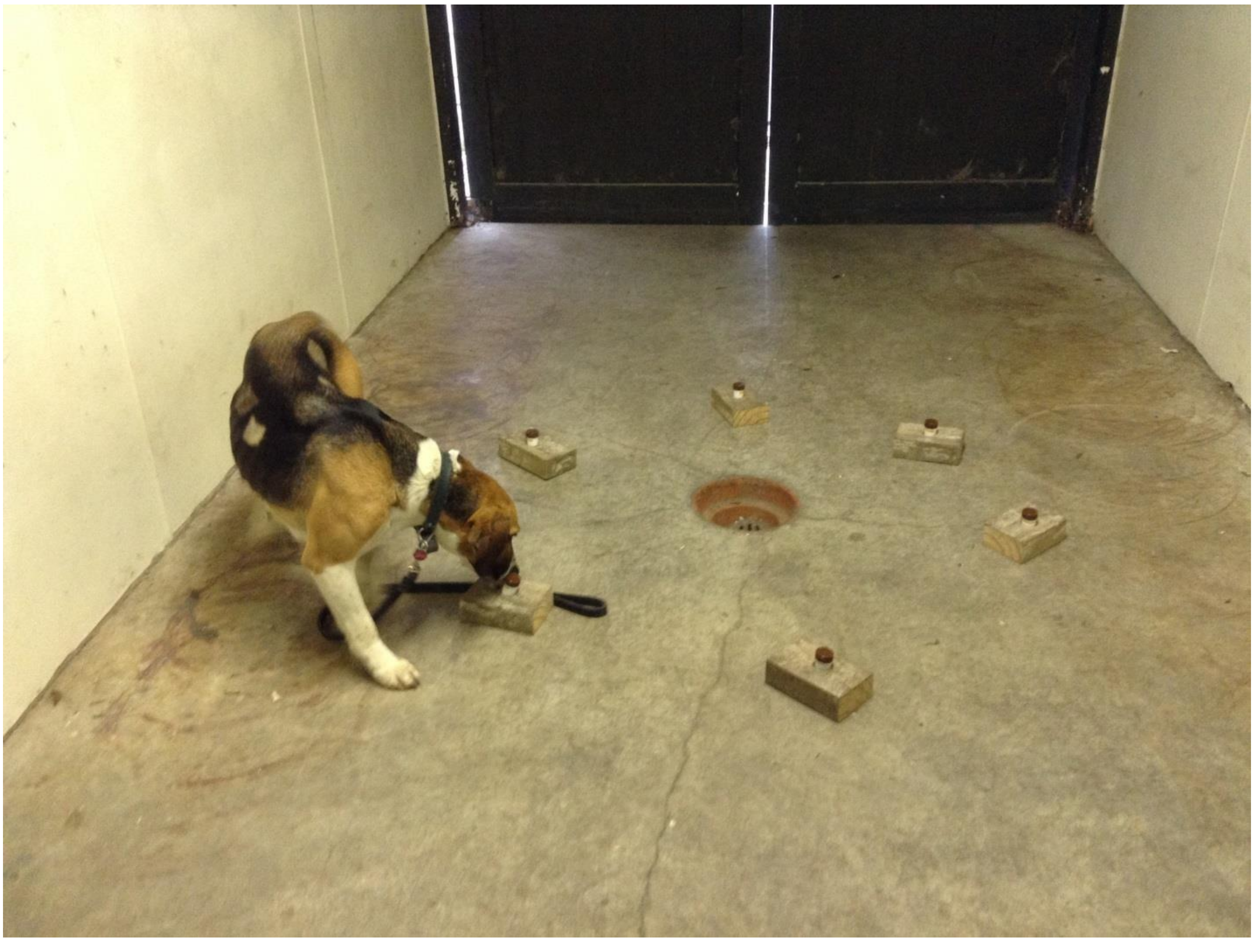
Explosive detector dogs (EDD) are required to locate and respond to bombs and other types of explosives which are composed of mixtures of different chemicals (Helton, 2009). Since World War II, dogs have been used extensively by the military to locate explosives (Furton & Myers, 2001). There are a large variety of explosives meaning that each of them is composed of different elements (Singh, 2007). The ratio of each component can also differ making it difficult for a single odour representative.

In order to train an EDD it must first determined what odour the dog is responding to. There are two ways to determine this, the first approach is to the train the dog with each individual component and then test to determine whether the dog responds to the real explosive (Helton, 2009). The second way is the opposite, where the dog is trained to detect the real explosive and then presented with the components (Helton, 2009). However, both this approaches have produced inconsistent results (Lorenzo et al., 2003). The optimal solution would be to train EDDs on an odour that is found in most explosives (Harper, Almirall & Furton, 2005). However, it would still be necessary to train the dogs on explosives that do not contain that specific odour.

Williams and Johnston (2002) found that dogs were able to remember at least 10 odours at any one time. The detection of the previously learned odours did not decrease as the number of substances trained increased. Interestingly, the amount of training required for a new odour decreased as more odour discriminations were trained (Williams & Johnston, 2002). There are advantages in both using instrumental methods and canines as detectors, however, detector dogs still represent the fastest, most versatile, reliable real-time explosive detection device available (Furton & Myers, 2001).

Chapter 3

Methods



Jade performing a run. Photo: Chloe Phoon

3.1 Dogs

Sixteen harrier hounds, 5 males and 11 females, were used in this study (Table 3.1). These harrier hounds were from Manawatu Hunt Club (Kellow Road, Bainesse, Himitangi). The ages of the dogs are related to their names, the older the dog the closer its name was to the beginning of the alphabet. Their ages range from 3-13 years (the exact ages were not known), with Bella being the oldest and Nemo the youngest (Table 3.1). The Massey University Animal Ethics Committee gave approval for the use of these dogs in the experiments described in this thesis

These dogs did not have any prior training except for a few that had been trained to sit. They were not trained in any type of detection work. They were lent to Massey University for research and teaching purposes because for various reasons they were not suitable for hunting.

They were kept in pens in pairs and were let out every day into paddocks to run around and exercise.

3.2 Location and Facilities

All training and experimental trials were done at a Massey University facility in Palmerston North, New Zealand. The initial bonding and sit training was done outdoors in an area with a dirt floor and enclosed by wire mesh and wooden frames (Figure 3.1). The training and experiments were done in a room to minimise distractions (Figure 3.2).

Figure 3.1 Outdoor facility where bonding and sit training was done. Photo: Chloe Phoon

Figure 3.2 Indoor facility where training and experiments were done. Photo: Chloe Phoon

3.3 Training Procedures

3.3.1 Bonding

These dogs had not had much contact with humans and were quite nervous around strangers. Bonding was done in order to gain their trust and allow for training. This also allowed me to observe the dogs so that the most suitable dogs for the trials could be identified. Dogs that were more curious and friendly were more likely to be candidates than those that were nervous and uninterested.

Every weekday for two weeks I helped the technician who looked after the dogs to feed them. This was done from the end of March till the middle of April 2014. Dogs were held in pens in pairs and chained up by their collars before they were fed so that they did not fight over food. They were fed at 7am in the morning and then let out to exercise and play. I spent about 20 minutes in each area playing with each dog.

Most of the dogs were afraid of me for the first few days. The females were particularly timid. The males were friendlier and did not hesitate to come up to me. After the two weeks of interaction, all the dogs were comfortable around me and were not afraid to come up to me. Each dog had its own temperament. Most of the females were mild natured and the males were more boisterous and energetic (Table 3.1).

Table 3.1 Characteristics of Harrier Hounds used in this study. Observations of their behaviour and temperament after two weeks.

Number	Name	Sex	Behaviour/Temperament (Observation after 2 weeks)
1	Bella	Female	Oldest dog. Not energetic and likes to sit down. Not as nervous as the other females.
2	Coe	Male	Oldest male. Sits in the corner most of the time and does not fight for attention.
3	Chrissy	Female	Quite mild natured, but when food is involved she becomes hyperactive.
4	Chorus	Female	She whimpers a lot for attention.
5	Dawn	Female	Scared of strangers and will bark at them. Does not crave attention.
6	Fay	Female	Quite a reserved dog and not energetic. Wary of strangers but will come up to a person once she is used to that person.
7	Gloman	Male	Not as boisterous and energetic as other males. Can be wary of strangers. Likes attention and will jump on people.
8	Golly	Female	Sweet natured dog. Does get picked on by the males but does not fight back.
9	Hana	Female	The most nervous and timid dog. Usually sits in the corner and keeps to herself. She will come when you call, but will not fight with the other dogs for attention.
10	Jade	Female	Sweet natured dog. She gets picked on by the males but does not fight back. She is the most agile.
11	Midget	Female	Quite a stubborn dog and can get aggressive. Scared of strangers especially males. However, once she is used to a person she will want attention.
12	Neat	Female	Likes to run around with the boys and is not as interested in human interactions.
13	Nemo	Male	Very friendly and energetic. Will jump on people, whether he knows them or not
14	Odin	Male	Most energetic dog. He feeds off the energy of others
15	Quick	Male	Not as energetic as the other males. He is the most nervous at of all the males and is scared of novel sounds.
16	Royal	Female	Extremely scared of strangers especially males. However once she is used to a person, she seeks attention.

3.3.2 Teaching the "Sit" Command

Once the dogs were comfortable with me, the next step was to teach them the "sit" command. Nine of the dogs (Bella, Chorus, Jade, Midget, Fay, Gloman, Nemo, Odin and Quick) had been taught the "sit" command previously by another student before this study. This training allowed me to observe their response to training and to teach them the reward system (positive reinforcement).

Positive reinforcement was used to train these dogs. Positive reinforcement is reinforcing a desired behaviour, such as sitting, when it occurs. In addition, a clicker was used as a conditioned reinforcer acting as a bridge between earning the food and getting the food (clicker training). This training was done to establish the clicker as a conditioned reinforcer by linking the sound to an unconditioned reinforcer (food). The clicker was used on a continuous rather than an intermittent basis, meaning that the dog always heard a click after it performed the desired behaviour.

From the middle of April till the middle of June, I worked with the dogs about 5 days a week. The dogs were divided into two groups (eight in each group) and each group was trained on alternate days. About 10 to 15 minutes was spent with each dog for each training session. Each session started with taking the dog for a short walk and then leading them into an enclosed area (Figure 3.1). Once in the enclosed area they were let off the leash. There were two ways in which they were taught to sit. The first way was to hold a treat (JerHigh Chicken and Bacon Masterpet Corporation Limited ©®™, Lower Hutt, New Zealand) over their head while saying the word "sit" so that while they looked up, they would automatically sit down (Figure 3.3). Once their backside touched the ground, the clicker was pressed and the dog was given a treat immediately. If this method did not work, the treat would be held over their head while I used my other hand or leg to push their rear down. Again, once their rear touched the ground, the clicker was pressed and a treat was given. The second method was required for most of the dogs. This was done about eight times, with each dog, in each session. In between each command the dog was allowed to walk around the enclosed area for a few seconds. Dogs that were too nervous or resisted their backsides being pushed down were excluded from further training (Table 3.2).

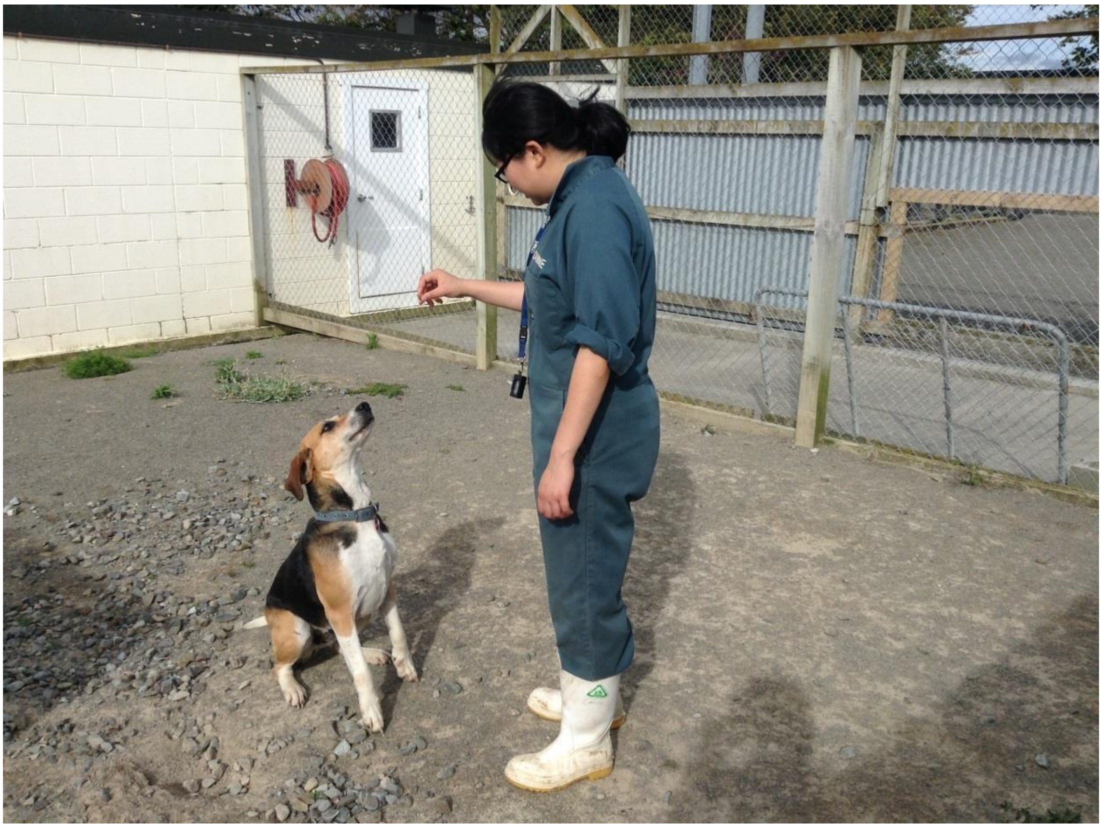


Figure 3.3 Teaching Golly the sit command by holding the treat over the dog's head. Photo: Chloe Phoon

Figure 3.4 Giving her a treat after she performs the task. Photo: Chloe Phoon

Table 3.2 Response of each dog after the first few days of teaching the "sit" command

Number	Name	Sex	Behaviour
1	Bella	Female	Naturally likes to sit and so once she realize that sitting would get a her treat, it was easy to get her to sit. However, she may not associate the word "sit" with a treat and is just sitting out of habit.
2	Coe*	Male	Did not bother to train Coe because of his age and his physical state.
3	Chrissy	Female	Gets excited when she smells food. She tends to sit, lie and jump when she is excited which makes it difficult for her to sit still.
4	Chorus	Female	Very food motivated. At the beginning, she would try to take the treat from my hand above her head instead of sitting and was a bit resistant when I tried to push her rear down. After a few commands, she put up less of a resistance and was easier to push her rear down.
5	Dawn	Female	Had to push her rear down to get her to sit, however, by the end of the first session she managed to do it on her own.
6	Fay	Female	Had to push her rear down and she did put up a bit of resistance at first.
7	Gloman	Male	One of the harder dogs to train because he did not want to listen to me. He also did not like it when his rear was pushed down and moved away.
8	Golly	Female	Was not very interested in the treats and took her awhile to actually eat one. This might be because she did not like this particular type of treat. This made it harder to train her. She did allow me push her rear down.
9	Hana*	Female	Did not allow her rear to be pushed down and freaked out. I decided to stop training her.
10	Jade	Female	Very food motivated. At the beginning, she would try to take the treat from my hand above her head instead of sitting and was a bit resistant when I tried to push her rear down. After a few commands, she put up less of a resistance and was easier to push her rear down.
11	Midget	Female	Had to push her rear down in order to get her to sit, however, by the end of the first session she manage to do it on her own.
12	Neat*	Female	Not as interested in food as the other dogs. She tried to take the treat out of my hand. She did not allow her rear to be pushed down at all and therefore decided not to continue train her.
13	Nemo	Male	Very food motivated. Had to push his rear down but did not put up much resistance
14	Odin	Male	Gets distracted very easily but is food motivated. Had to push his rear down in order to get him to sit.
15	Quick*	Male	A nervous dog. He was frightened by the clicker and also freaked out when I tried to push his rear down. Due to this, decided to not continue training him.
16	Royal	Female	Very food motivated. At the beginning, she would try to take the treat from my hand above her head instead of sitting and was a bit resistant when I tried to push her rear down. After a few commands, she put up less of a resistance and it was easier to push her rear down.

***Dogs that did not continue with training after the first few days**

After two weeks of training, most of the dogs did not require their rears to be pushed down physically to get them to sit (Table 3.3). However, some dogs still required the treat over their head in order for them to sit (Figure 3.3). The clicker was used throughout training. Odin and Gloman were excluded from training as they were too hard to handle.

Table 3.3 Progress after teaching them the "sit" command after two weeks

Number	Name	Sex	Behaviour
1	Bella	Female	Sits whenever she likes, but does realize that she gets a treat whenever she sits. However, she may not fully understand the command.
2	Chorus	Female	Still requires the treat over her head.
3	Chrissy**	Female	Sits with and without the command.
4	Dawn*	Female	Will sit when she sees the treat, and it does not have to be over her head.
5	Fay*	Female	Not as motivated to learn, but will sit when the treat is over her head.
6	Golly	Female	Still quite apprehensive, but will sit when the treat is over her head.
7	Jade	Female	Can sit without seeing the treat.
8	Midget**	Female	Will sit without seeing the treat, however, she does not listen all the time.
9	Nemo	Male	Will sit even without seeing the treat.
10	Royal	Female	She will sit, however, only after a few seconds after the command is given.

***Dogs that did not continue to the food training because they were too nervous in the testing room**
**** Dogs that completed the food training but did not continue on to the beetle training**

After a month of training, almost all of the dogs sat on command and without seeing the treat. Whenever they sat, the clicker was pressed and the behaviour was reinforced through treats.

Each dog was then introduced to the testing room in which the experiments would be done (Figure 3.2). The “sit” command was reinforced in the room. Jade, Chorus, Midget, Nemo, Bella and Chrissy were comfortable with the change of setting and still sat on command. Dawn, Royal, Golly and Fay were apprehensive and scared when they were first introduced to the testing room. They walked around the room with their tail in between their legs and did not listen to the commands. After a week, Royal and Golly got used to the room and were their regular selves again. However, Fay and Dawn refused to listen and were discontinued from training.

3.3.3 Equipment for Scent Training

Pottles and Blocks

Plastic pottles 5.5cm tall and 2.7cm in diameter were used (Figure 3.5). They were soaked in boiling water (~100°C) for 30 minutes in a tub before use. The pottles were then dried in direct sunlight on a clean sheet. After they were dry, they were kept in new bags until they were used. Disposable gloves were worn throughout this process.

6 wooden blocks were used to hold the pottles for the experiment and training. Each block was about 16cm x 10cm x 5cm (L x W x H), with a 3cm diameter hole in the middle to hold the pottle (Figure 3.6)

Dog Food

These dogs are experimental dogs. During this study there were concurrent studies using these dogs. One of them was food study, which meant that they had to consume a set diet. I therefore had to stop using Jerhigh Chicken and Bacon as treats. The “treats” that I fed them during the training and throughout the experiment had to be the same as their daily food. During the food A and beetle trials, half the dogs were on wet food (ground bone, beef mince, offal and vitamin and mineral supplement), while the other half were on dry food, Hill’s™ Science Diet™ - Adult Active (Hill’s Pet Nutrition (NZ) Ltd. ©™, Auckland, New Zealand). Twenty grams of dry food or fifty grams of wet food was used for each dog during each trial.

During the cockroach and the second round of food trials (food B), Pedigree –Working Dog Food (Mars NZ Ltd. ®™©Penrose, Auckland) (dry food) was fed to the dogs. Twenty grams of Pedigree –Working Dog Food was used for each dog during each trial. Therefore both the treat and food in the pottle were the same for the dog food trials.

Figure 3.5 Example of plastic pottle used in training and experiment. Photo: Chloe Phoon

Figure 3.6 Example of wooden block used in training and experiment. Photo: Chloe Phoon

Carpet Beetle Larvae

Australian carpet beetle larvae (*Antherenocerus australis*) were used in this study. They were caught from a house in Auckland, New Zealand and reared in Massey University (Palmerston North, New Zealand). They were kept in a glass tank (40cm x 23cm x 30cm) with carpet lining the floor. The glass tank was in a constant temperature room at a temperature of 21°C. The beetles were kept in darkness for most of the time other than when they were being used. Pieces of paper towel were placed on the carpet which was sprayed once a week to provide moisture for the insects. On top of the carpet lining were small pieces of carpet, about 50cm by 50cm, so that it was easier to transfer the larvae into the pottle. They were transferred by lifting the small pieces of carpet up and brushing the larvae that were underneath into the pottle.

Cockroach

American Cockroaches (*Periplaneta americana*) were used in this study. They were reared at Massey University in a glass tank (80cm x 60cm X 30cm). The floor was covered with wood shavings and the cockroaches had constant access to food pellets. A dish of water was also placed inside the tank and refilled when necessary. They were next to a window and were therefore exposed to the regular daily photoperiod.

Video Camera

Some of the training and all formal and blind tests were recorded on video camera. The video camera was a Sony DCR-SR20 (© 2010 Sony Corporation)

3.3.4 Training in the Experimental Model

Table 3.4 The schedule for all training and trials that were run for this study. The dogs were trained in between trials.

Stimuli	Training (2014)	Trials	
		Formal	Blind
Food A	15th June – 15th July	17th -29th July	-
Beetle larvae	21st Aug – 21st Sep	25th Sep & 3rd Oct	10th Oct
Cockroach	15th – 23rd Oct	24th & 31st Oct	7th Nov
Food B	-	15th & 22nd Nov	29th Nov

Food A

The food training and trials were designed to provide an initial indication of the dogs' ability to respond to a scent. Dog food was chosen because it was attractive to the dogs and had a strong smell which even humans could detect.

The training ran for one month (Table 3.4) and the trials were carried out for 5 days non consecutively. Before the trials were run, the dogs were trained to sit when they smelt food in a pottle. After the dogs were comfortable in the testing room and were able to sit on command, six blocks each with an uncapped pottle were placed in the room (Figure 3.2). The dogs were introduced to the pottles without food for the first week and therefore were not very interested in the pottles. After smelling one or two pottles, they would lose interest and start to walk and sniff around the room.

The next step was to place food in one of the pottles. Three pieces of dry food, Hill's™ Science Diet™ - Adult Active (Hill's Pet Nutrition (NZ) Ltd. ©™, Auckland, New Zealand), or about 5g wet food (ground bone, beef mince, offal and vitamin and mineral supplement) was placed into the pottle depending on what the dog fed on. There was a separate room inside the testing room, this room will be called the "waiting room" from now on (Figure 3.7 & 3.8). The dogs were put in that room while the test room was being set up and in between test runs.

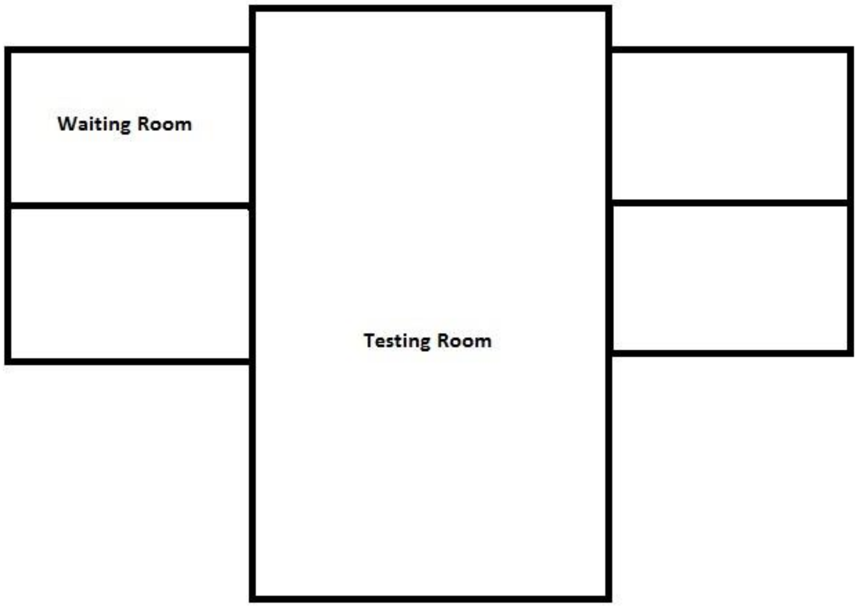


Figure 3.7 Diagram of the whole room.

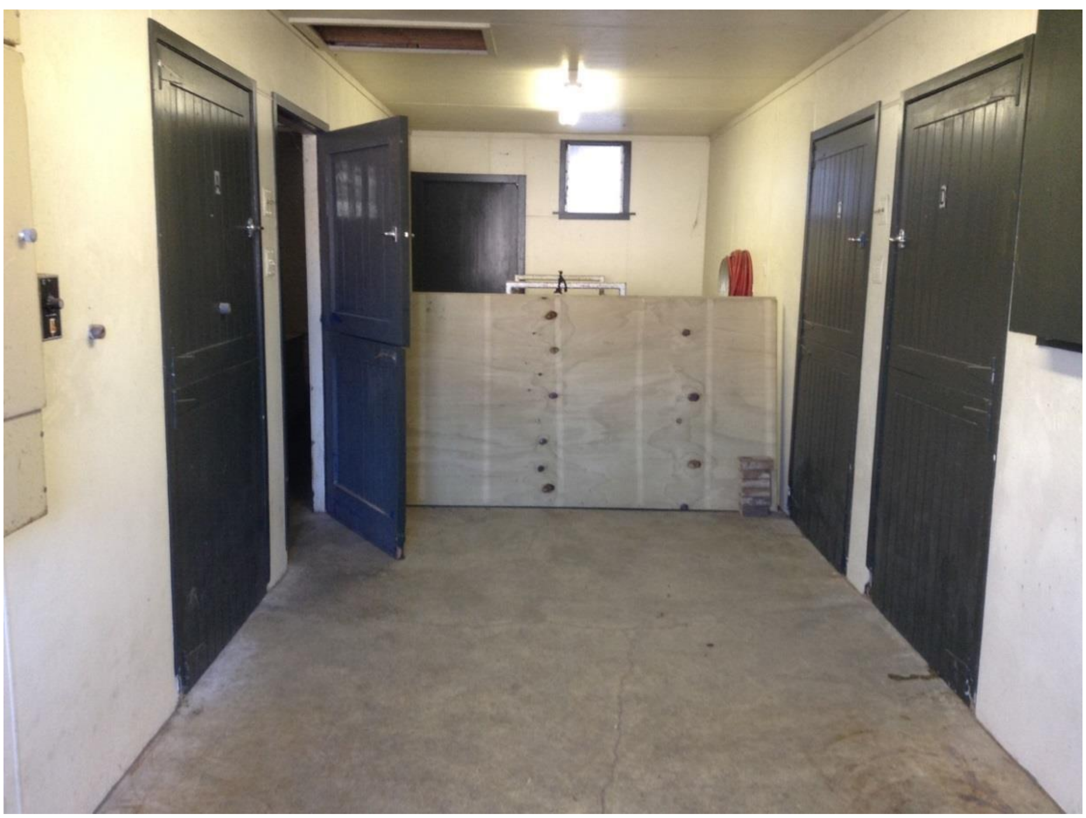


Figure 3.8 Picture of the room with the waiting room door open. Photo: Chloe Phoon

Each dog was brought into the testing room and led into the waiting room. The pottle with the food (target pottle) and the other five empty pottles would be placed into the blocks in a random order. Before the dogs were brought out I would say "Find food", this was the cue at the start of each run. The dogs were then led out on a leash and led towards each of the pottles which were arranged in a circle (Figure 3.9). At the beginning, the dogs' attention had to be drawn to the pottles as they were used to them being empty. This was done by pointing my finger at each pottle as they were led around the circle. Once the dog dropped its head to sniff the target pottle they were commanded to sit. Most of the dogs tried to get the food out of the pottle when they smelt it, so their head had to be pushed away and then they were asked to sit. When they sat, the clicker would be pressed and a treat (either wet food or dry food depending on their set diet) was given to them at the target pottle. This was one training run. Each dog was trained 4 times a week and completed 6-7 runs per day.

After a week, I did not need to point at the pottles anymore and the dogs would voluntarily sniff at each pottle. Each dog was still led on a leash around the testing room and when they reached the target pottle, they were commanded to sit. Once they sat the clicker was pressed and they were treated immediately. They would then be led into the waiting room, while the position of the pottle was changed. Both the target pottle and the block were moved together. After the location of the pottle was changed, the dog was let out of the waiting room and did the same thing again. All six pottles were replaced in between each dog.

After a month, the dogs began to sit on their own when they reached the target pottle. However, sometimes they would sit out of frustration or when they wanted a treat. I decided to stop training Midget and Chrissy after a month. Chrissy was too excited and sat all the time to get a treat. She was not interested in the pottles and only wanted the treats. Midget only listened when she wanted too. Once the dogs showed that they were capable of responding to the food, I started formal tests and recorded the results.

Beetle Larvae

After the dogs were trained to respond to food, they were then trained to respond to beetle larvae before the actual trials. Jade, Nemo, Bella, Royal, Chorus and Golly were the only dogs

Figure 3.9 Picture of how the blocks were arranged in experiments. Photo: Chloe Phoon

Figure 3.10 Bella being led around the circle of blocks and encouraged to smell each pottle. Photo: Chloe Phoon

used for this experiment. However, Chorus was put down half way through training due to a malignant tumour. The training ran for a month (Table 3.4) and the trials were carried out over three days non consecutively.

Since they previously were trained to respond to food I did not need to draw their attention to the bottles. Just like the food training, the dogs were on a leash and led around the circle of blocks with a pottle in each one (Figure 3.10). One of the pottles contained 10-13 live beetle larvae (target pottle) (Figure 3.11). For this training, the pottles were capped (holes were drilled into the cap) so that the dogs could not accidently inhale the larvae.

Each dog was brought into the testing room and led into the waiting room. The pottle with the beetle larvae and the other five empty pottles would be placed into the blocks in a random order. Before the dogs were brought out I would say "Find beetle", this was the cue at the start of each run. The dogs were then let out on a leash and led towards each of the pottle which were arranged in a circle (Figure 3.9). Once the dog dropped it head to sniff the target pottle they were commanded to sit. When they sat, the clicker would be pressed and a treat (either wet food or dry food depending on their set diet) was given to them at the target pottle. The dog was then led back into the waiting room while the position of the pottle was changed. This was one training run. After 6-7 runs the dog was returned to its pen and the next dog was led into the testing room. Each dog was trained four times a week. After a month of training them to respond to beetle larvae, I did two formal tests and a blind test.

Cockroach

After the dogs were trained to respond to food and beetle larvae, they were then trained to respond to cockroaches before the actual trials. Jade, Nemo, Bella, Royal and Golly were used for this experiment. The training ran for a month (Table 3.4) and the trials were carried out over three days non consecutively. The training for this stimulus was shorter than the first two because of time restrictions.

Figure 3.11 Beetle larvae placed in the target pottle. Photo: Chloe Phoon

Figure 3.12 An American cockroach in the target pottle. Photo: Chloe Phoon

Just like before, the dogs were on a leash and led around the circle of blocks with a pottle in each one. One of the pottles contained a live American cockroach (target pottle) (Figure 3.12). The pottles were also capped for this training and trials so that the cockroach could not escape.

Each dog was brought into the testing room and led into the waiting room. The pottle with the cockroach and the other five empty pottles would be placed into the blocks in a random order. Before the dogs were brought out I would say "Find cockroach", this was the cue at the start of each run. The dogs were then let out on a leash and led towards each of the pottle which were arranged in a circle (Figure 3.9). Once the dog dropped it head to sniff the target pottle they were commanded to sit. When they sat, the clicker would be pressed and a treat was given to them at the target pottle. The dog was then led back into the waiting room while the position of the pottle was changed. This was one training run. After 6-7 runs the dog was returned to its pen and the next dog was led into the testing room. Each dog was trained four times a week.

After a month of training them to respond to cockroaches, I did two formal tests and a blind test.

Food B

This experiment was done to see if the dogs could still respond to food. The trials were carried out over three days non consecutively (Table 3.4.). The dogs were only trained in between trials. However, the food that was in the pottle was different from the first training as the concurrent food trials that were going on had finished. Pedigree –Working Dog (Mars NZ Ltd. ®™©Penrose, Auckland) was used for this training and trials. Two formal tests and a blind was done, which was different from the first food trial as it did not have a blind test at the end.

3.4 Experimental Trials

3.4.1 Formal Tests

Protocol

The blocks and pottles were arranged in a circle in a random order in the testing room (Figure 3.9). All the pottles, including the target pottle, were placed into the blocks with disposable gloves. Before the dog was let out of the waiting room, the command was given to find the target pottle (e.g. “Find food” or “Find beetle”). This was the cue for the start of each run. The dog was then let out on a leash and walked around the circle to smell each pottle. Each time they sat at the correct pottle the clicker would be pressed and they were given a treat. After one run, they were led back into the waiting room while the location of the target pottle was changed. Both the pottle and block was shifted when the position was changed. This took about 2-3 minutes, and then the run started.

After each dog completed six runs, they were led back to their pen and the pottles were replaced. The used pottles were placed into a separate plastic bag from the clean pottles. Gloves were used when taking clean pottles out of the bag and placing them into the blocks. Each trial was recorded on video camera.

In order for a run to be recorded as a success the dog had to sit at the target pottle after sniffing each pottle only once. If they missed the target pottle they were led around the circle again. The trial was not a success if they did not identify the target pottle after the first lap around the blocks. If the dog sat at the wrong pottle before reaching the target pottle this was a false positive. The dog would not be treated and led on to the next pottle.

Trial 1 - Food

The target pottle contained food and either held 5g of wet food or 3 pieces of dry food (Hill’s™ Science Diet™ - Adult Active). Each dog did six runs per day and the tests ran over five days (i.e. five formal test) over two weeks for a total of 30 runs.

Trial 2 - Beetle Larvae

The target pottle contained 10-13 beetle larvae. This was recorded over two days (i.e. two formal tests) and each dog did six runs per day for a total of 12 runs.

Trial 3 - Cockroach

The target pottle contained a live American cockroach. This was recorded over two days (i.e. two formal tests) and each dog did six runs per day for a total of 12 runs.

Trial 4 - Food (Re-training)

For these trials 2 pieces of Pedigree –Working Dog Food was put into the target pottle. This was recorded over two days (i.e. two formal tests) and each dog did six runs per day for a total of 12 runs.

3.4.2 Blind Tests

The blind tests were done after the formal tests. An assistant helped with these trials. Like the formal tests the six pottles and blocks were arranged in a circle (Figure 3.9). I would first place the pottles into the blocks using disposable gloves and then tell the assistant where the target pottle was. At the start of each run, both the dog and I would be in the waiting room while the assistant changed the position of the target pottle. After she was done changing the position of the pottle, she would knock on the door to the waiting room to signal she was done and was going to leave the testing room. Once I heard the testing room door close, I gave the dog the cue to find the target and led the dog out on a leash and around the circle of pottles. The dog was led round and round the circle until it sat down. When the dog sat at a pottle, the clicker was pressed and the dog was given a treat. After it sat down, it was then led back to the waiting room and I would check to see if the dog got it right. This was one run. I would then call the assistant back in the room and then join the dog in the waiting room again while she changed the position. Each dog did six runs in the blind test and there was only one blind test for each stimulus. There was no blind test for the first food trial.

After each dog completed six runs, they were led back to their pen and the pottles were replaced. The used pottles were placed into a separate plastic bag from the clean pottles. Gloves were used when taking clean pottles out of the bag and placing them into the blocks. Each trial was recorded on video camera.

A run was defined as successful if the dog sat at the target bottle. Since I did not know which pottle was the target pottle, no false positives were recorded. Once the dog sat at a pottle that was considered its final choice and the pottle was checked after the dog was put back into the waiting room.

Trial 1 - Beetle Larvae

Trial 1 required the dogs to identify the pottle with the beetle larvae. The target pottle contained 10-13 beetle larvae.

Trial 2 - Cockroach

In trial 2 the dogs were required to identify the pottle with the cockroach. The target pottle contained one American cockroach.

Trial 3 - Food

In trial 3, target bottle contained 2 pieces of Pedigree –Working Dog Food in which the dogs had to identify amongst 5 empty pottles.

3.4.3 Statistical Analysis

The number of possible selections the dogs could make in each run was considered to be equal to the number of pottles they were presented with, which was six. This means that there was a 16.7% chance of success in each run if they were choosing at random. A run was considered successful when the dog found the target pottle on the first try (i.e. first pass around the circle) without any false positives, i.e. sitting at a pottle that did not contain the stimulus.

A dog was considered successful in a trial if it selected the correct pottle a certain number times above a threshold calculated using a binomial test. The threshold was a number of correct runs that was significantly different from chance (z-score had to be equal to or greater than 1.64 leading to a $p<0.05$). Table 3.5 shows the number of runs needed for a trial to be considered a success for each stimulus. For example, a dog would only be considered successful in the beetle larvae trial if it selected the target pottle in at least 13 of the 18 runs ($z = 1.83$, $p<0.05$).

Table 3.5 The criterion for a success for a dog in each trial. A binomial test was used to calculate the number of correct runs required to be significantly different from chance and therefore considered a success.

Trial/ Stimulus	n	Total number of runs	Number of correct runs required to be significantly different from chance ($p<0.05$)
Food A	5	30 (5 formal)	20
Beetle larvae	3	18 (2 formal & 1 blind)	13
Cockroach	3	18 (2 formal & 1 blind)	13
Food B	3	18 (2 formal & 1 blind)	13

A logistic regression was used to explore the relationship between stimulus (beetle/cockroach/Food A/Food B), type of test (Formal/Blind) and success in a run. The repeated measures created within dogs and multiple tests on the same day were accounted for by general estimating equations (GEE). When using GEE, the clustering was captured using a new variable that uniquely identified each dog and day combination.

Chapter 4

Results

Nemo. Photo: Chloe Phoon

4.1 Trial 1 – Dog Food A

Most of the dogs (five out of six) were successful in identifying the dog food in the pottle. The target pottle was correctly identified at an average success rate of 78.9%. The success rate appeared to increase as the trials progressed. Formal test 5 had more number of successes compared to trial 1, however more evidence and statistical analysis is needed to confirm this (Table 4.1). Each dog also appeared to improve their performance in this trial over time. For example, Nemo got 66.7% correct in his first formal test and got 100% in his final formal test. Success rates for individual dogs ranged from 56.7% to 93.3%. Bella was the only dog that did not succeed in this trial with 56.7% correct identifications, while Royal almost identified the target pottle in each trial with a success rate of 93.3% (Table 4.1). The raw data can be found in the appendix (Table 6.1, 6.2 & 6.3).

Golly was the hardest to train as she was not as food motivated as the rest. Nemo, Jade, Royal and Chorus learnt the quickest. Bella was also not as motivated, however, this is could be due to age. The dogs did sit down beside a pottle sometimes out of frustration or if they just wanted a treat.

Table 4.1 Results for food stimulus. This table shows how many successful runs each dog completed in each trial. Each trial was 6 runs and there were 5 trials, therefore there were a total of 30 runs. The results were calculated as the percent correct. A dog was considered successful if it identified the correct pottle 20 times or more out of 30 runs based on the binomial test (see Table 3.5). False positives were classified as a fail.

Dog	Trials					Total successful runs	Percentage success	Overall success
	1	2	3	4	5			
Jade	4	5	5	5	5	24	80	Yes
Bella	2	4	3	4	4	17	56.7	No
Royal	5	5	6	6	6	28	93.3	Yes
Nemo	4	4	5	6	6	25	83.3	Yes
Golly	4	3	5	4	6	22	73.3	Yes
Chorus	5	4	5	6	6	26	86.7	Yes
Total	24	25	29	31	33	142	78.9	5/6 dogs

4.2 Trial 2 – Beetle Larvae

None of the dogs succeeded in this trial. None of them came close to selecting the correct pottle in 13 runs, with Golly having the highest number of successful runs of 8. The target pottle was correctly identified in an average of 27.7% of the runs (Table 4.2). Success rates for individual dogs ranged from 0% to 44.4%. Bella performed the worst overall with 0% correct , while Golly got 44.4% correct (Table 4.2). The average percentage for formal tests was 35%, however it was 13.3% for the blind test.

The dogs behaved as if confused at the start of training as they were expecting to smell food. I needed to slow them down as they were used to the food trials and ignored the target pottle. During the trials most of the dogs did not select a pottle and went round the circle at least once, before sitting out of frustration. The dogs frequently looked at me for affirmation or for a signal when they could not detect anything.

Table 4.2 Results for carpet beetle larvae. This table shows how many successful runs each dog completed in each trial. Each trial was 6 runs and there were 3 trials (two formal and one blind), therefore there were a total of 18 runs. The results were calculated as the percent correct. A dog was considered successful if it identified the correct pottle 13 times or more based on the binomial test (see Table 3.5). False positives were classified as a fail.

Dog	Formal	Formal	Blind	Total successful runs	Percentage correct	Overall success
Jade	1	4	0	5	27.8	No
Bella	0	0	0	0	0	No
Royal	1	3	2	6	33.3	No
Nemo	3	2	1	6	33.3	No
Golly	4	3	1	8	44.4	No
Total	9	12	4	25	27.7	0/5 dogs

4.3 Trial 3 - Cockroach

None of the dogs were successful in this trial either, however, there was a higher average success rate of 45.5% compared to the beetle larvae trial (Table 4.3). Golly came close to the threshold number with 11 successful runs. Success rates for individual dogs ranged from 33.3% to 61.1%. Jade performed the worst overall with 33.3% correct, while Golly got 61.1% correct (Table 4.3). The average percentage for formal tests was 46.67%, however it was 36.6% for the blind test.

Table 4.3 Results for cockroach. This table shows how many successful runs each dog completed in each trial. Each trial was 6 runs and there were 3 trials (two formal and one blind), therefore there were a total of 18 runs. The results were calculated as the percent correct. A dog was considered successful if it identified the correct pottle 13 times or more (see Table 3.5). False positives were classified as a fail.

Dog	Formal	Formal	Blind	Total successful runs	Percentage correct	Overall success
Jade	3	1	2	6	33.3	No
Bella	3	2	2	7	38.9	No
Royal	3	2	2	7	38.9	No
Nemo	4	4	2	10	55.5	No
Golly	4	4	3	11	61.1	No
Total	17	13	11	41	45.5	0/5 dogs

4.4 Trial 4 – Dog Food B

Three out of the five dogs succeeded in this trial. The target pottle was correctly identified in an average of 74.5% of the runs (Table 4.4). Success rates for individual dogs ranged from 50% to 88.9%. Bella and Nemo were not considered successful as they did not reach the threshold, however Nemo was very close with 12 correct runs (13 runs would be significant from chance). Bella performed the worst with 39.2% correct, while Royal got 88.9% correct (Table 4.4). The average percentage for formal tests was 85%, however it was 60% for the blind test.

Trial 4 was carried out to see if the dog would still succeed in finding an attractive olfactory stimulus in the experimental model. It would seem that the dogs still remembered to sit at a pottle containing dog food, especially Royal and Golly who scored very high in the formal tests.

Table 4.4 Results for food B. This table shows how many successful runs each dog completed in each trial. Each trial was 6 runs and there were 3 trials (two formal and one blind), therefore there were a total of 18 runs. The results were calculated as the percent correct. A dog was considered successful if it identified the correct pottle 13 times or more (see Table 3.5). False positives were classified as a fail.

Dog	Formal	Formal	Blind	Total successful runs	Percentage correct	Overall success
Jade	4	4	4	16	88.9	Yes
Bella	3	3	3	9	50	No
Royal	6	6	4	16	88.9	Yes
Nemo	6	3	3	12	66.7	No
Golly	5	5	4	14	77.8	Yes
Total	24	20	16	67	74.5	3/5 dogs

4.5 - Differences in trials and dogs

Variation in the performance of individual dogs became apparent as the study progressed. Chorus's results were not included in the statistical analysis as she was put down after the first trial and therefore would have skewed the results. Royal had the highest overall success with an average rate of 67.9% while Bella performed the worst with an average success rate of 39.2%. Jade, Nemo and Golly had an average success rate of 56%, 63.1% and 65.5% respectively. Royal performed the best in food trials, however Golly had a higher detection success rate for the insect trials.

The number of correct runs differed for each trial, with the average number of correct runs for the food trials greater than both the insect trials. Food A had the highest number of correct runs with 78.9% of the runs ending in a success (Table 4.1). The beetle larvae had the lowest number of correct runs with only 27.7% correct runs (Table 4.2).

When the results of all the trials were compared, there was a statistically significant effect of the stimulus (p= 0.003) and type of test (p = 0.02). The dogs succeeded less when presented with the cockroach (Z = -3.76, p = 0.0002) and even less when presented with the beetle larvae (Z = -6, p = 0.0001) compared to the first presentation of food. There was no significant difference between food A and Food B (Z = -0.68, p = 0.5), this means that the dogs were just as successful in identifying food A and food B. The dogs also succeeded less during a blind test compared to a formal test for each trial (Z = -3.5, p = 0.0005) (Table 4.5). The highest probability of detection for a blind test was Food B (0.57; Table 4.5) and for a formal test, Food A (0.77; Table 4.5). Dogs performed the worst in the beetle larvae followed by the cockroach trial.

Table 4.5 Predicted probability of detection, and 95% Confidence Interval (CI), by stimulus and test type. Values obtained from a logistic regression model that used General Estimating Equations to account for repeat measures within dogs and multiple tests on the same day. Chorus's results were not included, so n=5 dogs.

Stimulus	Test Type	Probability of detection	95% CI
Food A	Formal	0.77	0.7-0.83
Beetle Larvae	Formal	0.33	0.22-0.47
	Blind	0.19	0.13-0.28
Cockroach	Formal	0.51	0.41-0.61
	Blind	0.33	0.25-0.42
Food B	Formal	0.74	0.64-0.82
	Blind	0.57	0.49-0.65

There were a total of 182 failed scent runs across all four trials with a total of 450 runs. The dogs selected the wrong pottle in 80 of the failed scent runs (44%). In 46 of the failed scent runs, the dogs did not select any of the pottles (25.3%). This usually happened in the beetle larvae trials. Fifty-two (27.5%) of the failed scent runs were false positives, in which the dogs chose an incorrect pottle before reaching the target pottle but did indicate at the target pottle subsequently. In four of the runs, the dogs did not complete the task because they were distracted by a certain smell in the room or loud noises outside (2.2%).

There are a few differences between trials that might have affected the results. First, food A had the most trials (5) compared to the other three trials (3). The cockroach trial had the shortest training (2 weeks) and there was only training in between trials for food B.

4.6 Dog Behaviour during Scent Trials

The dogs commonly exhibited a number of behaviours during the trials, such as:

- Hastily touching each pottle, but not sniffing or making a real effort to detect the target pottle.
- Sitting out of frustration when unable to detect the stimulus.
- Looking at the author for a signal after sniffing a pottle, as if uncertain.
- Looking at the author for a treat when uninterested in the task.
- Licking the caps of the pottles, especially when there is food in the target pottle.
- Continuing past the target pottle, although their body language (e.g. looking back at the pottle, sniffing at the pottle and then looking at me) suggested they recognized the scent.
- Sitting down and not wanting to move because uninterested in task or unsure what was being asked of them.
- Distracted behaviour such as smelling the room or attention directed at noises outside the room.
- Cautious when coming out of the waiting room after the assistant has left in blind tests.

Chapter 5

Discussion

Golly. Photo: Chloe Phoon

This study investigated whether these dogs could detect and respond to carpet beetle larvae. The primary finding of this study was that these dogs could detect food, but not Dermestid beetle larvae and cockroaches. This was unexpected because other studies have shown that dogs are able to detect pest insects even at low densities (Table 5.1) (Waller & Ellis, 1976; Nakash, Osem & Kehat, 2000; Lin, et al., 2011). Therefore the author considered it unlikely that these dogs were not able to detect carpet beetles.

The dogs in this study were used because they were available. They were selected based on trainability and not for any particular aptitude for scent discrimination work. They had no prior scent detection training. Some aspects of the methodology in the study may have influenced the results and could be modified for future research. However, the ability to find food A and B suggested that the model was appropriate. Differences in the aptitude and consistency of individual dogs, the handler's influence on the dog, trial design and distractions may also have affected the results.

5.1 The Dogs

Overall the dogs were successful in detecting food, however they were not able to detect the beetle larvae and cockroaches. Some dogs were better than other dogs. For example, Golly achieved an average success rate of 67.9% while Bella achieved an average success rate of 39.2%. Food B had the highest probability of detection for a blind test (57%), while Food A had the highest probability of detection for a formal test (77%) (Table 4.5). The insect that was of interest in this study was carpet beetle larvae, which these dogs were only able to detect at a low rate of 27.7%. This could be due to several reasons, which include dog breed, learning inflexibility, and temperament.

5.1.1 Dog Breed

The dogs used in this study were harrier hounds. They are a breed of medium-sized hound and are believed to be a descendant of hounds brought to England by the Normans. The harrier was originally and still is used in packs to hunt hares (Anon, 2014). Today they are also kept as house pets. The first harrier hound was imported to New Zealand by ship and the first hunt was formed in 1873 (Milne & Tucker, 2003). Hounds hunt by sight (sigh hounds) and smell; however harrier hounds only hunt by smell. A hound searches for a hare by following the 'line' of scent to their hiding place (Milne & Tucker, 2003). Thus they were expected to be suitable for detecting these beetles.

The first thing that a huntsman looks at when choosing a harrier hound is its ability to hunt. The temperament, soundness and hunting patterns are then considered (Milne & Tucker, 2003). A hound is not selected by the huntsman if it has a nervous temperament or won't "pack up" or come back when it is called. The harrier hounds that were used in this study were rejected by the huntsman because of one or more of these reasons. Therefore these individual dogs were most likely not the best candidates for the job.

Table 5.1 The ability of dogs to detect pest insects or substances infected with pest insects.

Study	Dog Breed	No. of Dogs	Target Scent	Average Success (%)
Brooks, Oi & Koehler, 2003	Beagles German Shepherd	5 1	Eastern subterranean termites	95.93
Errico, 2012	Labrador retriever mix Beagle	2 1	Asian Longhorned Beetle frass	80-90
Lin et al., 2011	Beagle	3	Fire ants	98
Nakash, Osem & Kehat, 2000	Golden Retriever	2	Ooze from Red Palm Weevil infested trees	100
Pfiester, Koehler & Pereira, 2008	Beagle Beagle mix Chinese crested Jack Russell terrier	3 2 1 1	Beg bugs and viable bed bug eggs	95-97.5
Rolon et al., 2011	German Shepherd	1	Reduviidae bugs	Not mentioned, but was able to detect
Waters et al., 2010	English Springer-Spaniel	1	Bumblebees	100

The results of this study were poor compared with other research that has assessed the ability of dogs to detect insect pests (Table 5.1). The dogs in this study could only achieve an average success rate of 27.7% for the beetle larvae and 43.3% for the cockroach. However the studies listed below achieved a success rate between 80-100%. The dogs in each of these studies were trained to detect the target insect or substance using methods similar to those used in this study. However, this is the first time harrier hounds have been formally used as detector dogs.

The most common dog breed used to detect pest insects were beagles (Table 5.1). This is interesting because harriers and beagles are closely related to each other. Both these breeds are scent hounds and were bred for hunting purposes (Anon, 2014). It is safe to assume that both these breeds would have the same detection capabilities both being scent hounds. The failure of this experiment was most likely not due to the breed of the dog but rather because of other reasons such as age, temperament, rearing and previous experience.

5.1.2 Learning inflexibility

Age may play an important part in the cognitive and physical ability of a dog to detect a desired scent. The dogs used in this study were no longer puppies and Bella who was the oldest, was 13 years old. The brains of older dogs have less cognitive ability, meaning that it takes more time for them to learn a task or switch from on task to another (Adams et al., 2000a, 2000; Chan et al., 2002).

These harriers may not be able to learn more than one scent because they were too old. Older dogs may suffer from age-related cognitive dysfunction in which they slowly become impaired in any of four different ways. These include orientation in the immediate environment, social interactions with human family members, learning and memory and sleep-wake cycles (Ruehl et al., 1995; Neilson et al., 2001; Nagasawa et al., 2012). A study done by Neilson et al. (2001) found that 27.5% of the dogs aged 11-12 had impairments in one or more categories and 10.0 % had impairments in two or more categories. Dogs aged 15-16 were even worse with 67.6% of them having one or more impairments (Neilson et al., 2001). The exact age of the dogs in this study were not known, however, all of them were over 3 years old. Bella was 13 years old and performed the worst in all four trials, which could be due to her inability to learn and memorize the new scents.

It is possible that the dogs in this study were incapable of learning a new task after the food trials. Chan et al. (2002) found that aged canines were not able to learn new visuospatial and memory tasks and showed reduced maximal working memory capacity compared with young canines. Reversal learning required subjects to inhibit responses to previously correct stimuli and to shift responses to a new stimulus-reward contingency (Adam et al., 2000b). It requires the animals to “unlearn” an initial association. Aged dogs were more persistent in responding to the previously rewarded object compared to young dogs (Milgram et al., 1994). A study done on beagle dogs found that older dogs were impaired on both the initial learning of size tasks and the reversal of original reward contingencies (Tapp et al., 2003).

The dogs may have developed “habit learning” which is inflexible, slow, unconscious, automatic and insensitive to reinforcer devaluation (Seger & Spiening, 2011). Habit learning requires repeated trials compared to rapid learning which is learning through a single trial. There is a correlation between a dog’s age and the number of errors made. The older the dog, the more mistakes it made (Nagasawa et al., 2012). The dogs used in this study took a month to learn how to sit and a month to learn the experimental model (siting at the target pottle) which seems quite slow. In an experiment, dogs were taught to use rubber balls as tokens to obtain food when a ball was dropped into an opening in the top of a machine (Ellson, 1937). When the food machine was rotated during the early stages of training, it resulted in the complete breakdown of the response. They required further training in order for to maintain a high success rate.

As a dog gets older, the brain shows decreased efficiency. It is the failure of inhibitory mechanisms that account for many aspects of age-related cognitive dysfunctions (Persad et al., 2002; Tapp et al., 2003). The frontal lobe is the first to deteriorate and may explain the increase in distraction found in older dogs as the result of their reduced frontal cognitive control capacity (Lavie, 2010). Bella who was the oldest, had the worst results overall with an average success rate of 39.2%. She was also the least motivated and was easily distracted.

5.1.3 Temperament and Motivation

The temperament of a dog is very important when it comes to selecting a working dog (Svartberg, 2002; Maejima et al., 2007). There is a relationship between temperament and performance. Playfulness, interest to chase, exploration and fearlessness are traits that are found in higher performing dogs. Bolder dogs have been found to perform better compared to shy dogs (Svartberg, 2002). Working dogs such as guide dogs are usually rejected due to temperament such as fearfulness and aggressiveness rather than their physical abilities (Goddard & Beilharz, 1983; Weiss & Greenberg, 1997; Serpell & Hsu, 2001).

The dogs in this study may have been unsuccessful in learning to detect the carpet beetle larvae because of their shy temperament. Some of the dogs used in this study were rejected by the huntsman because of undesirable temperaments, such as fearfulness. The dogs that I chose for my study were friendlier than the other dogs in the colony, however they were still quite nervous dogs and they did not socialize much with humans. They also had no interest in chasing after objects and were scared of a big rubber ball when it was placed in their pen. Dogs such as Hana and Quick were easily scared and did not like the sound of the clicker. They were easily distracted when they heard loud noises outside the room. They also did not perform when there were strangers around and would not listen to the commands given by the author. Svartberg (2002) found that fearful dogs were more distracted compared to dogs that were less fearful. Therefore they may have less motivation to learn in the experimental model.

Dogs performing repetitive scent exercises can become bored, leading to a decrease in performance (Kerley & Lazo, 2003). However, it is unlikely that the dogs became bored because of repetition as they each only completed six runs per day over a month and there were even signs of improvement in Food A. Narcotic dogs are required to complete about ~600 runs using ~100 different training aids before they are put to work (Davenport, 1984). Some of the dogs may instead have become distracted or bored when they were frustrated. They would sit down out of frustration because they were confused or if they just wanted a treat. This happened most of the time in the beetle larvae trials after the dogs went around the circle at least once. They may also have not been as motivated to perform as they were trained on a full stomach.

Training was always in the afternoon, while the dogs were fed in the morning. The beetle larvae and cockroach were also not attractive stimuli, which may have affected the dogs' motivation to find them and hence they gave up easily.

5.2 Limitations in methodology

5.2.1 Dog selection

The dogs were not assessed for their suitability, although the sit training and trial 1 (the food trial) was designed to give a basic indication of their temperament and trainability. Selection was solely based on the author's observation which was open to individual bias. As an inexperienced handler, the best dogs may not have been chosen for the experiment which could have been one of the reasons why the success in some of the trials was low. The sample population of the dogs was not randomly selected. They were all from a dog colony loaned to the university and hence the dogs were chosen based on availability. These dogs were also rejected by the huntsman.

Most of the dogs in this study were females, with the assumption that they were easier to handle. Females tend to be smaller in size and hence more manageable. They also tend not to be as aggressive and therefore would not require as firm a correction as males (Bradshaw, et al., 1996). Working dogs such as guide dogs or detection dogs are most often rejected for behavioural reasons rather than physical abilities (Serpell & Hsu, 2001; Maejima et al., 2007; Rooney et al., 2007). Hence age was not a consideration during selection, as there was more concern about their ability to listen and their temperament rather than their age. This might however have affected the results, as was discussed.

5.2.2 Equipment

The original plan to sterilise the pottles was to autoclave them, however, they melted in the intense heat. So it was then decided to wash them in hot water but without the use of soap, so that they would not be contaminated with any soap smell. However, this means that there may have been residual scent of each of the stimuli in the pottle or the saliva of the dogs on the caps. Drying the pottles and caps in the sunlight and outdoors could also have allowed odours from the environment to contaminate the pottles. The blocks were also not washed or wiped after each run and therefore there may be residual scent on them. However, this potential scent of error was probably slight.

5.2.3 Stimuli: Dog food, beetle larvae & cockroach

Dog food is obviously attractive to the dogs but it is also familiar. It is most likely the only scent that they were used to compared to the other two stimuli. Research has suggested that familiarity with scent achieves a higher detection rate by dogs (Kurz et al., 1996; Komar, 1999).

The beetle larvae were taken from a house in Auckland. Each individual insect was not identified through a taxanomic key (device used to identify unknown organisms). It is possible that not all the larvae were of the same species and therefore confused the dogs when they were trying to identify them. About 11-13 larvae were used each time, however, there could have been a different ratio of different species of larvae each day.

The beetle larvae were only placed into the target pottle just before the trial. Since we do not know how strong the larvae would smell to the dog, the odour may not have permeated fast enough in the pottle. Hence the dogs could not detect them. The larvae were also very small ranging from about 2mm-4mm. The dogs may not have been able to smell them because they were too small. However, previous research has shown that dogs could detect 10 fire ants with an average success rate of 98% (Lin et al., 2011).

There was a higher success rate in identifying cockroaches compared to the beetles. This could be due to several reasons such as size and smell. Cockroaches are very much bigger and have a stronger smell.

5.2.4 Time

The time taken to train each dog to detect each stimulus was about a month and only two weeks for the cockroach trials. Each dog had the same amount of training and time for each stimulus. Since these dogs had no prior training, the training time may have been too short for them to learn the task. Studies have shown that older dogs take a longer time to learn a task

(Adams et al., 2000a; Nagasawa et al., 2012). This study also produced similar results. Bella who was the oldest took the longest to learn and had the most errors during trials.

These dogs may have been able to detect the beetle larvae if they were given more time. In a study looking at whether dogs could detect bed bugs, the dogs went through 90 days of initial training before being used in the actual experiment (Pfiester, Koehler & Pereira, 2008). In another study, dogs that were trained to detect mines were trained and tested over a period of five months (Fjellanger, Andersen & McLean, 2002). A month of training may not have been sufficient enough for these dogs.

5.2.5 Training methods

Positive reinforcement training with the use of a clicker was the method used to train these dogs. Clicker training is often used in detection training (Fjellanger, Andersen & McLean, 2002; McCulloch et al., 2006) because it is suggested that it reduces training time (Pryor, 1999, 2005). Osthaus, Lea & Slater (2003) found that clicker trained dogs learnt the basic behaviour of pulling a string out of a box to obtain food faster than those that were not clicker trained. The learning time is reduced because of three mechanisms (Pryor, 1999, 2005):

- The clicker acts as a conditioned/secondary reinforcer whereby an initially neutral stimulus gains reinforcing value through its repeated pairing with the primary reinforcer.
- The clicker may act as a marking signal, which serves to inform the subject that it has earned the primary reinforcer.
- The clicker serves as a bridge.

However, a study done by Smith and Davis (2007) showed that clicker training increased resistance of extinction but did not decrease training time of a simple operant task in domestic dogs. It took just as long to train a dog to perform a task with a conditioned reinforcer compared to using just a primary reinforcer (food). There were also no differences between horses which received the conditioned reinforcer plus primary reinforcer and those which received only the primary reinforcer in regards to the number of trials it took for them learn an operant task (Williams, Friend & Archer, 2004). A clicker may therefore not be necessary for scent detection training and a primary reinforcer would be enough.

5.2.6 Trial Design

These trials required dogs to identify the target pottle from five empty pottles, this means that they were simply selecting the one pottle that had a different scent. Decoy pottles should have been added in the food trial in order to determine that the dogs were specifically detecting the dog food. The other two trials had very low scores, hence it is likely that the dogs could not even smell the difference between the target pottle and the empty pottles. It also possible that the scent was not relevant to the dogs. They did not create an association between indicating the target pottle and getting a reward.

During the blind tests, the clicker was pressed every time the dogs sat at a pottle even if it was not the target pottle. This was done because I did not know which pottle was the target pottle. However, this may not have been the best idea as it reinforced the dog when it chooses the wrong pottle. This would have confused the dogs and decreased overall performance.

The dogs were also a bit more nervous during the blind tests when they entered the room after the assistant had left. The dog and I waited in the waiting room while the assistant moved the blocks around in between trials. During this period the dogs could hear the blocks being moved around, their ears pricked up and turned their head towards to the door. When they came out of the room, they were more cautious and sniffed the air as they came out as if they smelt something different about the room. This made them distracted and the four trials that were not completed all happened during blind tests. This may have been one of the reasons why the dogs performed poorly in the blind tests compared to the formal tests. Royal had an average success rate of a 100% for Food B in the formal trials but only 66.7% in a blind test (Table 4.6).

5.3 Handler influences

One of the most important factors that could have affected the results was the person involved in training the dog. The experience of the trainer or handler plays a crucial role in the success of training a working dog. This was the first time the author trained dogs for scent detection and was not experienced in observing dog behaviour. It is possible that I did not choose the most suitable dogs for this task during the selection process. Insufficient training, handler error and varying handling motivation are common reasons that a dog's performance decreases (Smith et al., 2003; Wasser et al., 2004)

The formal tests had higher success rates compared to blind tests for all stimuli (Table 4.6). It is possible that the dogs were responding to signals from the author instead of using their nose. One of the ways the author could have signalled to the dog without realising it was slowing down at the target pottle. While walking around the circle she may have walked slower when reaching the target pottle and focused more attention at it. The dog may have felt the change in pressure in the leash and collar whenever passing by the target pottle. Dogs are able to find hidden food through human gestures including pointing, head turning, nodding and gazing toward the target (Soproni et al., 2001; Reid, 2009; Kundley et al., 2014). Szetei et al. (2003) found that dogs chose the incorrect container when they observed a human pointing at the incorrect container even though they were permitted to sniff the containers beforehand.

One of the main differences between a formal test and a blind test was that the author did not know where the target pottle was. Handler beliefs can affect the outcome of scent detection tests (Lit, Schweitzer & Oberbauer, 2011). There were more incorrect responses when handlers were falsely told the correct containers. It most likely that the dogs were not only responding to scent but additional cues by the handlers and the same may have been true in the blind tests (Szetei et al., 2003; Lit, Schweitzer & Oberbauer, 2011).

Mood and motivation may have affected the dogs' performances. As the author wanted the dogs to have a high success rate, she did become disappointed or frustrated when they were unable to correctly respond to the target pottle. The performance of dogs can deteriorate when handlers become emotionally involved in the outcome of the testing (Settle et al., 1994).

5.4 Uncontrolled variables

There were some uncontrolled variables that may have impacted on the dogs' success throughout the study. The dispersal of scent particles and the concentration of odour are strongly influenced by moisture and temperature (Murlis, Willis & Carde, 2000; Weisburg, 2000; Lasseter et al., 2003). All trials were held in a controlled indoor facility, hence weather was not a problem. There were a few noise distractions occasionally such as dogs barking, cars driving or people passing by.

5.5 Future recommendations

If this experiment were to be done again, there are several things that would be changed or done differently.

5.5.1 The Dogs

The dogs used in this study had a nervous temperament because they did not socialize much with humans. Even though they did get used to the author, they were easily distracted by noises outside of the testing room and were more cautious when the assistant was around. It would be advisable to use different dogs, whether it be breed or from a different source. The breed was not much of a concern compared to the temperament, as other studies have used a range of dog breeds for scent detection (Brooks, Oi & Koehler, 2003; Lorenzo et al., 2003; Smith et al., 2003; Pfiester, Koehler & Pereira, 2008). Dog breeds included Beagles, German Shepherds, Labrador Retrievers and Jack Russell Terriers. The exact temperament for the dogs in each of the studies were not known, however they appeared to have been highly motivated and were training to be scent detector dogs. Potential dogs should have a friendly temperament and a high play drive. Dogs that are willing to please or are used to following commands, whether it be basic commands such as “sit” or detection commands such as “find”, would be ideal. These could include pet dogs that have had obedience training or dogs that have experience in scent detection.

The dogs used in this study were relatively old to start detection training. The youngest dog was 3 years old. As a dog grows older, their brains show less cognitive ability and impaired learning (Adams et al., 2000a, 2000b; Chan et al., 2002). They become harder to train and it takes longer for them to learn new tasks. It would be better to use dogs that are between 1-4 years old, or at least those that had started scent training at a young age. Younger dogs also tend to be more energetic and motivated compared to older dogs. Older dogs, such as Bella, should not have been included in this study.

The sample size for this study was five dogs. A larger sample size could be used to obtain more significant results especially within each trial. However the average number of dogs used in insect detection studies range from 1-7 dogs (Table 5.1). Hence, the number of dogs used in this study was probably sufficient for this experiment.

Additionally, it is advisable that future detector dogs be accurately selected and trained and evaluated. Some recommendations for selecting and evaluating dogs include (Smith et al., 2003):

- Evaluating the dog's response to a particular toy or food.
- Selecting a dog with a strong play or prey drive.
- Evaluating a dog's ability to stay motivated with simple repetitive tasks.

5.5.2 Training

Time is an important factor. More time should be spent training each dog on the beetle larvae and cockroaches. The dogs in this study were trained for a month on beetle larvae and two weeks on the cockroach. In other studies, most of the dogs were trained for at least 3-5 months for scent detection (Fjellanger, Andersen & McLean, 2002; Pfiester, Koehler & Pereira, 2008). It is advised to increase training time to 4-5 times a week for at least 3 months. It would also be better to increase the number of runs completed each day during training to about 10 -15.

The dogs in this study may have become confused when switching from one task (food) to another task (beetle larvae). The main question in this study was whether these dogs could detect carpet beetle larvae. Based on this study they were unable to, with a success rate of only 27.7%. This is extremely low compared to other pest detection studies (Table 5.1). Though most of the studies used similar dog training methods to this study, it is highly likely that they did not start them of with food detection training. In this study, the dogs started with food training to investigate their capability and to evaluate the appropriateness of the experimental model. These dogs, however, were not capable of learning a new task when the stimulus was switched to the beetle larvae. Many studies have shown that aged dogs are incapable of reversal learning or "unlearning" an association (Milgram et al., 1994; Adam et al., 2000b; Chan et al., 2002). If this experiment again were to be done again, it would be advisable not to start with food detection training and instead go straight to beetle larvae training. This would hopefully create the desired association between the reinforcement and the detection of beetle larvae.

5.5.3 Trial Design

The number of beetle larvae in the pottle may not have been sufficient for the dogs in this study to detect. The target pottle contained about 10-13 beetle larvae for each trial. If this experiment were to be done again, more beetle larvae should be put in the pottle especially during the training period. This would hopefully create a stronger odour for the dogs to detect. In a termite detection experiment, dogs were trained on clothes that were covered in termites (about 300 termites). During the trials they used up to 160 termites. In another study, the dogs were trained with wooden boards containing about 100 dead fire ants (Lin et al., 2011). Based on these studies, the number used for this study may have been too low.

During the blind trials, the dogs' behaviour was reinforced when they sat at a pottle regardless of whether it was the target pottle. This is not advisable for future experiments as it would have reinforced the dog to sit at any pottle. This would confuse the dogs and they would sit any pottle in order to get a treat. If this experiment were to be done again, the dog could be rewarded when it goes back into the waiting room rather than at the pottle itself. This would motivate the dog to perform in the trials without creating an association with the wrong pottle. Another option would be not to reinforce them at all during the entire run.

It is possible that the dogs were detecting the difference in scent between the pottles instead of identifying the scent itself. In future experiments, decoy pottles should also be set up among target and empty pottles. This should be done after the dog has learnt to associate the desired scent with the reinforcer. The decoy pottles may contain other insect pests or even human scent (which is commonly found in homes). This would strengthen the association between the desired scent and reinforcer, rather than detecting the difference in scent between pottles. Something else that could be done to strengthen the association would be to let the dog smell the target stimulus before each run. For example, during the cockroach trials the dog would be allowed to smell a pottle containing a cockroach and then asked to find the cockroach (i.e. finding a scent that was presented to it).

Recommendations for future training and trial designs:

- Expose dogs to trials that contain target and decoy pottles.
- Condition the dog to associate the desired scent with a reinforcer before the trials.
- Establish a strict training schedule (about 4 times a week) for about 3-5 months.
- If possible an experienced trainer or handler should train the dogs.

5.5.4 Conclusions

In conclusion, the dogs were able to identify food A and B but were unsuccessful in detecting the carpet beetle larvae and cockroaches. Their ability to detect food A and B, suggested that the experimental model was appropriate and it was other factors that contributed to the failure of the experiment. This included individual temperament and aptitude, handler's influences and training methods. Future research should try using a different set of harrier hounds or a different breed to detect carpet beetle. The use of detector dogs can help with earlier discovery and identification of infested areas and thus reduce the use of pesticides. Temperament in working dogs is also another area that should be focused on because it affects the selection and trainability of a dog.

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Midget and Nemo. Photo: Chloe Phoon

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Appendix

Table 6.1 The target pottle contained a few carpet beetle larvae. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise. 1* indicated one false positive before finding the target pottle, this was also classified as a fail.

		Runs						
		1	2	3	4	5	6	Percentage Correct
Bella	Formal	0	0	0	0	0	0	0
	Formal	0	0	0	0	0	0	0
	Blind	0	0	0	0	0	0	0
Jade	Formal	1	0	0	0	0	0	16.7
	Formal	0	0	1	1	1	1	66.7
	Blind	0	0	0	0	0	0	0
Royal	Formal	1	0	0	0	0	0	16.7
	Formal	0	1	1	0	1	0	50
	Blind	0	1	1	0	0	0	33.3
Nemo	Formal	0	0	0	1	1	1	50
	Formal	1	0	1	0	1*	0	33.3
	Blind	0	0	1	0	0	0	16.7
Golly	Formal	1	1	1*	0	1	1	66.7
	Formal	1	1	0	0	0	1	50
	Blind	0	0	1	0	0	0	16.7

Table 6.2 The target pottle contained one cockroach. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise. 1* indicated one false positive before finding the target pottle, this was also classified as a fail.

		Runs						
		1	2	3	4	5	6	Percentage Correct
Bella	Formal	1	0	1	0	1	0	50
	Formal	0	0	1*	1	0	1	33.3
	Blind	0	0	1	1	0	0	33.3
Jade	Formal	1	0	1	1	1*	0	50
	Formal	1*	0	1*	0	1	0	16.7
	Blind	0	0	0	1	1	0	33.3
Royal	Formal	1	1	1	0	0	0	50
	Formal	1*	1	1*	0	1	0	33.3
	Blind	1	0	0	0	1	0	33.3
Nemo	Formal	0	1	1	1*	1	1	50
	Formal	1	1	1	1*	1*	1	50
	Blind	1	1	0	0	0	0	33.3
Golly	Formal	1	1	1*	1	1	1*	66.7
	Formal	1	0	0	1	1	1	66.7
	Blind	1	0	0	1	1	0	50

Table 6.3 The target pottle contained dog food B. 1 indicates a successful scent exercise, 0 indicates a failed scent exercise. 1* indicated one false positive before finding the target pottle, this was also classified as a fail.

		Runs						
		1	2	3	4	5	6	Percentage Correct
Bella	Formal	1	1	1*	0	1	1*	50
	Formal	1	1*	1*	1*	1	1	50
	Blind	0	1	0	0	1	1	50
Jade	Formal	1	1*	1	0	1	1	66.7
	Formal	1	1	0	1	0	1	66.7
	Blind	1	0	1	1	0	1	66.7
Royal	Formal	1	1	1	1	1	1	100
	Formal	1	1	1	1	1	1	100
	Blind	1	0	1	1	1	0	66.7
Nemo	Formal	1	0	0	1	1	1	66.7
	Formal	1	1*	1*	1	1	0	50
	Blind	1	0	0	1	1	0	50
Golly	Formal	1	1	1	1	0	1	83.3
	Formal	1	1	1	1	1*	1	83.3
	Blind	1	1	1	0	1	0	66.7