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**Further Examination of Cross-Modal Association in Canine (*Canis familiaris*) Scent  
Detection: Extending Research on Training Dogs to Identify Multiple Odours**

A thesis

Submitted in fulfillment

of the requirements for the degree of

**Master of Applied Psychology in Behaviour Analysis**

at

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by

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THE UNIVERSITY OF  
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## **Abstract**

Dogs' superior olfactory capabilities and trainability have led to widespread use of dogs for scent detection research and work. Previous research has largely focused on dogs' ability to detect and discriminate single odours, however more research is needed to understand dogs' ability to use multiple sensory modalities to identify and discriminate odours. Continuing research started by Campbell-Smith (2024), the current study hypothesized, a) dogs are capable of using cross-modal association to match odours to images of shapes and b) the inclusion of an error correction procedure and physical screen border on the touch screen where the images are presented will increase dogs responding accuracy and decrease biases towards specific shapes and screen quadrants, previously observed by Campbell-Smith. Four dogs were trained using shaping and chaining to engage in a conditional discrimination task using an automated scent delivery carousel and touch screen. Challenges faced early on during the initial conditional discrimination sessions prompted the inclusion of a simple visual discrimination task and an errorless learning procedure. The findings were largely consistent with Campbell-Smith, in that all dogs had above chance (50%) accuracy rates overall, but none met the mastery criteria (80%) overall. The correction procedure and physical touch screen border did reduce overall biases in all dogs, but did not increase responding accuracy enough to meet the mastery criteria. This suggests that the procedures used in these experiments may not be optimal for training dogs to accurately match odours and visual stimuli. Alternative procedures should be investigated in the future. The current findings provide more information as to dog's cross-modal identification capabilities, as well as further understanding of dogs' visual capabilities and a comparison of dogs' accuracy on conditional discrimination with and without an errorless learning procedure.

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## Table of Contents

Abstract.....	i
List of Tables.....	v
List of Figures.....	vi
Chapter One Introduction.....	1
Introduction.....	1
Background information.....	2
Continuation of previous research.....	4
Key Behavioural Concepts.....	5
Cross-modal association.....	9
Aims of current study.....	12
Chapter 2 Methods.....	13
Participants.....	13
Equipment.....	14
Solution Preparation.....	18
Sample Preparation.....	19
Training Procedures.....	19
Experimental Procedures.....	22
Data Analysis.....	25
Chapter 3 Results.....	27
Simple Visual Discrimination.....	27
Conditional Discrimination Task with Errorless Learning Procedure.....	33
Conditional Discrimination Task Without Errorless Learning Procedure (ELP).....	40
Quadrant Position Bias.....	46
Shape Bias.....	47
Sniff time and response time.....	49
Chapter 4 Discussion.....	52
Summary of Overall Findings.....	52
Implications.....	58
Limitations and Recommendations for Future Research.....	60
Conclusion.....	62
References.....	63

Appendix A: Guidelines for Solution Preparation.....	67
Appendix B: Guidelines for Sample Preparation.....	69
Appendix C: Guidelines for Training Dogs for Scent Detection Work Using Automated Apparatus.....	71

## **List of Tables**

Table 1 Participant information	14
Table 2 Simple visual discrimination images	21
Table 3 Errorless learning procedure (ELP) images	25
Table 4 Comparison of descriptive statistics for dogs first and second attempt on unsuccessful ELP level	34
Table 5 95% binomial confidence intervals for dogs' overall accuracy on the CD task without the ELP	41
Table 6 Sniff time and response time for each response type (ms)	51

## **List of Figures**

Figure 1 Scent delivery carousel	15
Figure 2 Position of nose port and touch screen in experimental room	17
Figure 3 Touch screen with images	17
Figure 4 Indie's Simple Visual Discrimination Data	28
Figure 5 Ralph's Simple Visual Discrimination Data	29
Figure 6 Tessa's Simple Visual Discrimination Data	30
Figure 7 Tilly's Simple Visual Discrimination Data	31
Figure 8 Gizzy's Simple Visual Discrimination Data	32
Figure 9 Indie CD task with ELP Data	36
Figure 10 Ralph CD task with ELP Data	37
Figure 11 Tessa CD task with ELP Data	38
Figure 12 Tilly CD task with ELP Data	39
Figure 13 Indie Conditional Discrimination Data	42
Figure 14 Ralph Conditional Discrimination Data	43
Figure 15 Tessa Conditional Discrimination Data	44
Figure 16 Tilly Conditional Discrimination Data	45
Figure 17 Comparison of shape presentations and selections in each touch screen quadrant	47
Figure 18 Comparison of shape presentations and shape selections	49

## **Chapter One**

### **Introduction**

#### **Introduction**

Dogs (*Canis familiaris*) are widely recognised as having outstanding olfactory capabilities, which far exceed those of humans as well as many other species of animal (Kokocińska-Kusiak et al., 2021). The olfactory sense is primary for dogs, which make them reliable and valuable assets to humans when detecting hazardous or illegal substances, such as narcotics and explosives, or identifying the presence of illnesses in humans, such as cancer or diabetes. Dogs often also play a key role in search and rescue missions for missing persons and endangered species (Singletary & Lazarowski, 2021). Dogs are also considered highly trainable, typically responding well to reinforcers such as praise and treats, and often work well alongside human counterparts in a variety of circumstances and environments (Singletary & Lazarowski, 2021). Dogs scent detection capabilities are considered to be not only versatile and reliable, but also one of the most cost-effective methods of scent detection available to humans (Browne, Stafford & Fordham, 2006).

In scent detection tasks, such as detecting explosives or illegal substances, dogs are typically trained to detect one odour at a time using their olfactory sense, and to indicate that the odour is present using a behavioural signal, such as sitting or barking (Johnen, Heuwieser & Fischer-Tenhagen, 2017). There is a gap in the current research as to whether dogs are capable of detecting and discriminating multiple odours simultaneously using multisensory perception, eg. detecting the odour then identifying it using a second sensory modality, such as light or sound.

The use of cross-modal sensory identification could lead to more efficient communication with humans as to which odour the dog has identified.

### **Background information**

Dogs have extraordinary capabilities to detect and identify very complex odours, (Kokocińska-Kusiak et al. 2021). One contributing factor is the extremely high density of olfactory receptor cells, proportional to the size of their nose (Stejskal, 2022). Dogs have up to 300 million olfactory receptors which far exceeds that of most other animals (Muppidi et al., 2021). Humans, for example, only have approximately five million olfactory receptors. The high concentration of their olfactory receptors increases dogs' sensitivity to odours and allows them to identify and discriminate odours they are sniffing, even at very low concentrations of parts per trillion (Kokocińska-Kusiak et al. 2021). These receptors also contribute significantly to dogs' outstanding abilities to (among other things) track odours over distance and time and recognise people, other animals and places they have previously encountered (Stejskal, 2022).

During sniffing, dogs inhale through two distinct olfactory pathways in their nasal cavity, which allows for the inhalation of two separate odours simultaneously through each nostril (Stejskal, 2022). This allows for bilateral comparison of the odours to occur, which in turn can strengthen the identification of odours through increased intensity of the odour and source localisation. Dogs also have unidirectional air flow in both nostrils, which allows for an extended exposure to the odour, which can also allow for easier and faster identification of the odour (Stejskal, 2022). The main olfactory epithelium (MOE), one of the main olfactory pathways, is responsible for the dogs' sense of smell (Kokocińska-Kusiak et al. 2021). The MOE contains specialised olfactory neuron cells which enable dogs to detect odours, identify scents and navigate their environment by sending signals to the brain's olfactory bulb. The olfactory bulb is

a specialised area of the brain which is responsible for processing and distributing information sent by the MOE (Kokocińska-Kusiak et al. 2021).

Dogs also have the ability to perceive, recognise and discriminate visual stimuli (Byosiere et al., 2018, Barber et al., 2020). Dogs' vision is not as sophisticated as humans, with dogs having roughly 20/75 visual acuity, compared to 20/20 vision in a human, which indicates that stimuli which would be clear to dogs from 20 feet away would be just as clear to humans from 75 feet away. Beyond 20 feet away, those same stimuli would become increasingly blurry to dogs and therefore, harder to see and discriminate (Miller & Murphy, 1995; Byosiere et al., 2018, Barber et al., 2020). Additionally, dogs have dichromatic vision, which only allows them to see colour on a spectrum of blue and yellow but lack human's ability to see reds and greens (Byosiere et al., 2019). Dogs do, however, have superior peripheral vision to humans, with their field of vision spanning approximately 240 degrees, compared to human's 180 degrees (Byosiere et al., 2018). Dogs are also capable of recognising familiar human faces and can be trained to recognise visual cues and signals such as hand gestures or objects, which also demonstrates their capacity for visual learning and memory (Byosiere et al., 2018; Barber et al., 2020).

Given that multimodal sensory perception is a necessary skill for most species to survive and adapt in different environments, it stands to reason that dogs would also possess the necessary capabilities and have the capacity to apply these skills in a wide variety of situations. Multimodal sensory perception involves the integration of information from different sensory modalities into a unified perception, for example, enjoying both the smell and taste of food. To date, however, there has been little research on dogs' ability to engage in multimodal sensory perception. The current gap in the research on multimodal sensory perception in dogs also applies to the research on applications for dogs using cross-modal sensory identification.

Investigating the extent to which dogs have the ability to make cross-modal sensory identifications of stimuli could have significant real-world applications. For example, if dogs are able to signal which odour they are smelling by indicating on an image or object, as opposed to just sitting or barking, this would allow the dogs to identify the odour using their olfactory sense and communicate the information to humans through visual identification of a corresponding visual stimulus. Using cross-modal sensory identification could increase the efficacy and reliability of dogs' communication with humans by engaging the strengths of each respective species (i.e. olfactory identification for dogs and visual identification for humans). These skills could potentially be applied to existing real-world applications for dogs working alongside humans, such as dogs trained to detect illegal substances/explosives or illnesses.

### **Continuation of previous research**

The current study aimed to continue and expand on the research started by Campbell-Smith (2024), which examined the ability of dogs to match target and non-target odours with visual black and white images of shapes using arbitrary matching-to-sample training. The current research aimed to gain more understanding of dogs' ability to select visual stimuli which have been arbitrarily matched with specific olfactory stimuli. This research also aimed to identify methods that can be used to train dogs in arbitrary odour and visual matching, so they are able to identify and discriminate both visual and olfactory stimuli and communicate this information effectively with humans. The current study aimed to replicate the training methodology used by Campbell-Smith (2024) to train domestic dogs and aims to continue to gather evidence to improve our understanding of the extent of dogs' abilities to engage in cross-modal sensory identification using olfactory and visual stimuli.

## Key Behavioural Concepts

Reinforcement, as defined by B. F Skinner (1958) describes any event or stimulus which strengthens behaviour, increasing the likelihood that the behaviour will occur again in future. Reinforcement is a key principle in operant conditioning, which can be defined as a form of learning whereby the behaviour is strengthened or reduced based on its consequences (i.e. reinforcement or punishment) (Skinner, 1938; Bouton, 2007). Reinforcement can be positive or negative and always works to strengthen (increase) a behaviour. Positive reinforcement is often a key aspect of training animals to learn new skills.

Another key aspect of operant conditioning is the three-term contingency, which consists of three key components: antecedent, behaviour and consequence (McSweeney & Murphy 2017). The antecedent is a stimulus or event that is present in the environment immediately prior to the occurrence of an operant behaviour, which is then followed by a consequence, either positive (reinforcement) or negative (punishment) (Mangiapanello & Hemmes, 2015; McSweeney & Murphy 2017). Skinner (1953) explained the three-term contingency as the occurrence of the consequence, which is contingent upon the behaviour, which occurs in the presence of a discriminative stimulus ( $S^D$ ) or an antecedent (Skinner, 1953; Mangiapanello & Hemmes, 2015). If an antecedent or  $S^D$  is not present then it cannot elicit the behavioural response, which in turn does not result in the corresponding consequence. Repeated pairing of an antecedent stimulus, or an  $S^D$ , and the behavioural response through operant conditioning increases the likelihood of the consequence occurring (Skinner, 1953; Mangiapanello & Hemmes, 2015; McSweeney & Murphy, 2017). An example of the three-term contingency is the presence of a dog's owner saying "sit" (antecedent) evokes the behaviour of the dog sitting, which is then followed by positive reinforcement (consequence) in the form of a treat. Without

the presence of the verbal command “sit” ( $S^D$ ), the behaviour of the dog sitting is unlikely to occur.

Simple discrimination, defined as the ability to differentiate two or more stimuli based on simple characteristics, such as size, colour, etc., is another key aspect of operant conditioning and has been used to assess humans' and animals' abilities to identify and discriminate visual stimuli (Saunders & Spradlin, 1989; Sugnaseelan et al., 2013). While it is limited, there has also been some research into dogs' ability to engage in simple visual discrimination tasks. One such study by Autier-Dérian et al. (2013) examined dog's ability to visually distinguish between different species based on their physical characteristics. They investigated this ability in dogs with both dog and “non-dog” species (such as humans, rabbits and horses). The dogs were shown two images, one of a dog and one of a non-dog species, simultaneously (physically separated by a wall) from a vantage point where they could view both images at equal distance then, on the command of the experimenter stood behind them, where required to move towards one of the two images and put their paw on the screen to indicate their choice (Autier-Dérian et al., 2013). At first, the selection of dog species images was reinforced ( $S^+$ ) until the dogs were able to generalise and exclusively choose dog images no matter what other non-dog species was  $S^-$ . This was then reversed so the selection of non-dog species images was reinforced ( $S^+$ ) and the selection of dog species were  $S^-$ , until the dogs were able to generalise and exclusively choose the non-dog images. Autier-Dérian et al.'s (2013) results suggested that the domestic dog participants were able to visually discriminate dog species and familiar non-dog species (such as humans) in 2D picture form to a high level of accuracy, however the dogs were less accurate with less familiar non-dog species (such as horses and goats).

Errorless learning, first introduced by Terrace (1963) as an alternative to trial and error procedures, describes a process of stimulus fading during discrimination tasks, whereby the incorrect stimulus (S-) is introduced gradually while maintaining the correct stimulus (S+) at full intensity to increase the likelihood of the correct stimulus being chosen, thereby reducing the likelihood of errors. Terrace (1963) conducted a study with two groups of pigeons being trained to discriminate visual stimuli (red or green circles), one group with trial and error (S+ and S- always presented at identical brightness) and the second group with errorless learning (S+ was always presented at full brightness and colour and the S- was gradually faded in using increased intensity until S+ and S- are at identical brightness). Terrace (1963) found that, compared to trial and error procedures, errorless learning helped to minimise errors by decreasing the likelihood of interaction with the incorrect stimuli.

Handley et al., (2023) conducted a study with dogs, aiming to replicate the results found by Terrace (1963), comparing the effects of errorless learning versus trial and error for dogs doing a simple visual discrimination task with blue and yellow coloured images of circles (since dogs cannot see red and green). Handley et al., also split the dogs into two groups, errorless learning and trial and error and taught to signal a choice between either a yellow or a blue circle displayed on a wall covered with a black sheet. The dogs had 30 seconds to make a choice, and their responses were recorded as either correct, incorrect or non-response if the dog failed to make a choice within the 30 seconds allowed per trial. After the initial training, the errorless learning group began the discrimination task using errorless procedures, where the brightness of the incorrect image (S-) was faded, starting at 20% brightness and gradually increased by 20% until the dogs were able to begin the simple discrimination task with both S+ and S- at equal brightness. The trial-and-error group only completed the simple discrimination task with both S+

and S- at equal brightness. Handley et al., (2023) found that, compared to the dogs in the trial-and-error group, the dogs in the errorless learning group made fewer errors when doing the simple discrimination task with both S+ and S- at equal brightness. This suggests that training dogs to do discrimination tasks using an errorless learning procedure prior to a trial-and-error procedure could reduce errors and improve overall accuracy.

Conditional discrimination, defined as how an individual's response to a discriminative stimulus depends on the presence of a conditional stimulus, is an extension of simple discrimination (Nevin, Cate & Alsop, 1993; Pérez & Polín, 2016). An example of conditional discrimination is a dog sitting to receive food only when their owner has food and gives the command "sit". The dog sitting in the presence of both the food and the command from their owner is then followed by the dog receiving the food as reinforcement for sitting on command. Repeated exposure to these environmental cues (i.e.. "sit" command paired with food in presence of owner), allows for discrimination between different behaviours and the corresponding reinforcing consequences. By contrast, if the owner was to give the "sit" command to the dog when they do not have food, the dog is less likely to sit because although the "sit" command cue is present, there is no food present.

An example of conditional discrimination is Matching-to-Sample (MTS), which can be defined as a behavioural training method where an individual is reinforced for selecting the correct stimulus from an array of comparison stimuli which matches or is associated with the sample stimulus that was presented first (Sample & Lube, 2018). There are two types of MTS, identity and arbitrary. Identity MTS is when the sample stimulus and the correct comparison stimulus are visually identical, for example matching a red sock with another red sock. Lazarowski, et al. (2021) conducted an identity MTS study with domestic dogs using their

olfactory sense as the primary sensory modality. Lazarowski, et al. (2021) trained domestic dogs to sniff a sample odour, then sniff an array of three comparison odours and indicate on the comparison odour which matches the sample odour by sitting next to it. Findings show the dogs were able to discriminate the correct comparison stimulus from the array at a rate significantly above chance, exceeding their baseline performance, which suggests that dogs have the ability to perform identity MTS tasks using their olfactory sense (Lazarowski, et al., 2021).

Arbitrary MTS is when the sample stimulus and the correct comparison stimulus are visually different but have been associated through operant conditioning, for example matching a red sock with a green ball (Sidman, 2000). There is no inherent similarity between the two stimuli, they have been arbitrarily related through repeated pairings (Fields & Verhave, 1987; Sidman, 2000). Cross-modal matching is a form of conditional discrimination and can be defined as the process of identifying and associating information across different sensory modalities (Choi et al., 2018). For example, smelling coffee and then tasting coffee. By definition, multi-modal or cross-modal sensory matching is arbitrary MTS, as it is impossible for any two or more stimuli accessed through different sensory modalities to be topographically identical, such as an olfactory stimulus and a visual stimulus (Fields & Verhave, 1987; Sidman, 2000). To date, other than the research started by Campbell-Smith (2024), there has been no research into dogs' ability to engage in arbitrary MTS tasks using cross-modal sensory identification and matching.

### **Cross-modal association**

The aim of previous research conducted by Campbell-Smith (2024) was to investigate the capacity for domestic dogs to communicate olfactory information (which odour they are smelling) using visual image discrimination (ie. cross-modal association). Campbell-Smith's (2024) methods were adapted for dogs from Youngentob et al. 's (1990) identity odour matching

research with rats to investigate whether rats are able to detect changes in the quality of a specific odour. The rats were put into a scent apparatus, which consisted of a central odour sampling port and five response tunnels. Youngentob et al. (1990) conducted research with rats to investigate whether animals can use cross modal association to identify olfactory stimuli and communicate this information effectively with humans.

Youngentob et al. (1990) designed a cross-modal sensory apparatus, referred to as an odorant confusion matrix, made up of five response tunnels attached to a central odour sampling tunnel. The rats were required to break a photobeam to release a sample of the target odour, then hold their nose in the beam for a minimum of 700 msec, which was signaled to the rats by a 2-KHz tone. The rats were then required to choose the response tunnel containing the corresponding odour to the sample odour and press the target at the end of the tunnel to indicate their choice. The correct choice resulted in reinforcement, the incorrect choice did not. This procedure was adapted for dogs in the study conducted by Campbell-Smith (2024) and the current study with the use of a carousel scent delivery apparatus, where the dogs were trained to poke their noses into a segment containing one of two odours for a minimum of 1000 msec to activate the touch screen. The dogs would then indicate on the touch screen (also using a nose poke) on one of two visual images of black and white shapes, which had been arbitrarily selected to correspond with an odour.

Campbell-Smith (2024) had seven domestic dog participants in her study, four of whom had been involved in previous scent detection research. Of the seven participants, six participated in the research past the initial training stages. Campbell-Smith (2024) used three odours, C1 (linalool), C2 (cinnamaldehyde) and C3 (amyl acetate), with C2 functioning as the target odour (matched with a circle) and C1 and C3 as non-target odours (matched with a cross). The dogs

were initially only introduced to C1 and C2, then once they met the mastery criteria (responding at least 80% correct across trials) for the target odour (C2), they were then introduced to C3. The dogs were trained to first poke their nose into the odour sampling port for a minimum of 1000ms, which activated the adjacent touch screen to show the two images. The dogs would then use their nose to poke one of the images. If their choice was correct (cross after smelling either C1 or C3 and circle after smelling C2) the dog, then received reinforcement in the form of a treat from an automated feeder. If the dog made the incorrect choice, they moved on to the next trial without reinforcement. Of the six dogs who participated past the training stages, only one dog (Penny, one-year-old German Shepherd) met the mastery criteria (at least 80% accuracy across three consecutive sessions) and was introduced to odour C3. There was also evidence of an overall, consistent position bias towards the top and bottom segments on the left side of the touch screen.

Campbell-Smith (2024) found that domestic dogs are capable of engaging in arbitrary MTS using cross-modal sensory identification (olfactory and visual) with better than chance accuracy. However, the speed of the dogs' skill acquisition, overall mediocre performance on the arbitrary MTS task, and touch screen position bias could potentially be addressed by implementing a few procedural changes. One such suggestion was the addition of a physical screen border to divide the four segments of the touch screen. This could make the four quadrants more distinct and eliminate the occurrence of borderline responses occurring by physically separating the four quadrants.

The other procedural change suggested by Campbell-Smith (2024) was the implementation of a correction procedure, whereby if a participant chooses the incorrect image, they then repeat the identical trial until they make the correct choice. Campbell-Smith (2024) also suggested that the addition of a correction procedure could also help to reduce the screen

position bias. Lazarowski, et al. (2021) implemented correction trials immediately after a dog indicated on the wrong comparison odour. These trials consisted of the exact same trial being repeated until the dog indicated on the correct comparison stimulus. This allowed the dog to have multiple opportunities to make the correct MTS association through repetition (Lazarowski, et al., 2021).

### **Aims of current study**

The current study aimed to continue and expand on the research started by Campbell-Smith (2024). Consistent with Campbell-Smith's (2023) research, it is hypothesised that dogs have the capacity to complete cross-modal arbitrary matching-to-sample tasks with better than chance accuracy. In addition to this primary aim, it is also hypothesised that the addition of a correction procedure and physical screen border will increase the overall accuracy of responding and reduce the screen position bias relative to Campbell-Smith's (2024) previous research.

## **Chapter 2**

### **Methods**

#### **Participants**

All dogs who participated in the current research were recruited from the community, through means such as advertising on social media, flyers on community notice boards, or through word of mouth and family members, as well as pre-existing scent detection research participants whose owners had expressed interest in participating in future projects. Prospective participants and their owners came to the research facility to determine the dog's suitability to participate in the research. The dog's level of food motivation, level of arousal within the environment, and comfort level with the apparatus and the researcher, particularly when their owner was not present in the lab, was assessed. If a dog was lacking in food motivation or exhibited signs of distress at any point, they would not be eligible to continue with the research.

The current study had five session times, two mornings (Monday and Tuesday) and three afternoons (Monday, Tuesday and Wednesday). One dog, Indie, was the only pre-existing participant from Campbell-Smith's (2024) research who was available to continue participation in the current research. Indie would come to the lab Monday and Tuesday mornings. Due to her previous participation, Indie was able to start the conditional discrimination task straight away without any additional training. Four additional dogs, Gizzy, Tilly, Tessa and Ralph, who were recruited through family members of the researcher, began sessions two months after Indie and would come to the lab Monday, Tuesday and Wednesday afternoons. Prior to commencing the research, these four dogs had to first undergo training to use the relevant apparatus.

**Table 1***Participant information*

Name	Breed	Age	Sex	Weight	De-sexed
Indie*	Weimaraner	3 years	F	31kg	Yes
Gizzy+	Border collie	6 years	M	22kg	Yes
Tilly	Border collie	6 years	F	19kg	Yes
Tessa	Labrador	3 years	F	34kg	No
Ralph	Rough collie X Golden retriever	3 years	M	32kg	Yes

\* Continued from Campbell-Smith (2024) study

+ Did not complete initial training or participate in any conditional discrimination tasks

Whilst in the lab, dogs were kept in separate crates, each fitted with a soft bed, blanket and bowl of water. Each dog was walked outside at least once every two hours. All experimental conditions and procedures were approved by the University of Waikato Animal Ethics Committee (Protocol 1192).

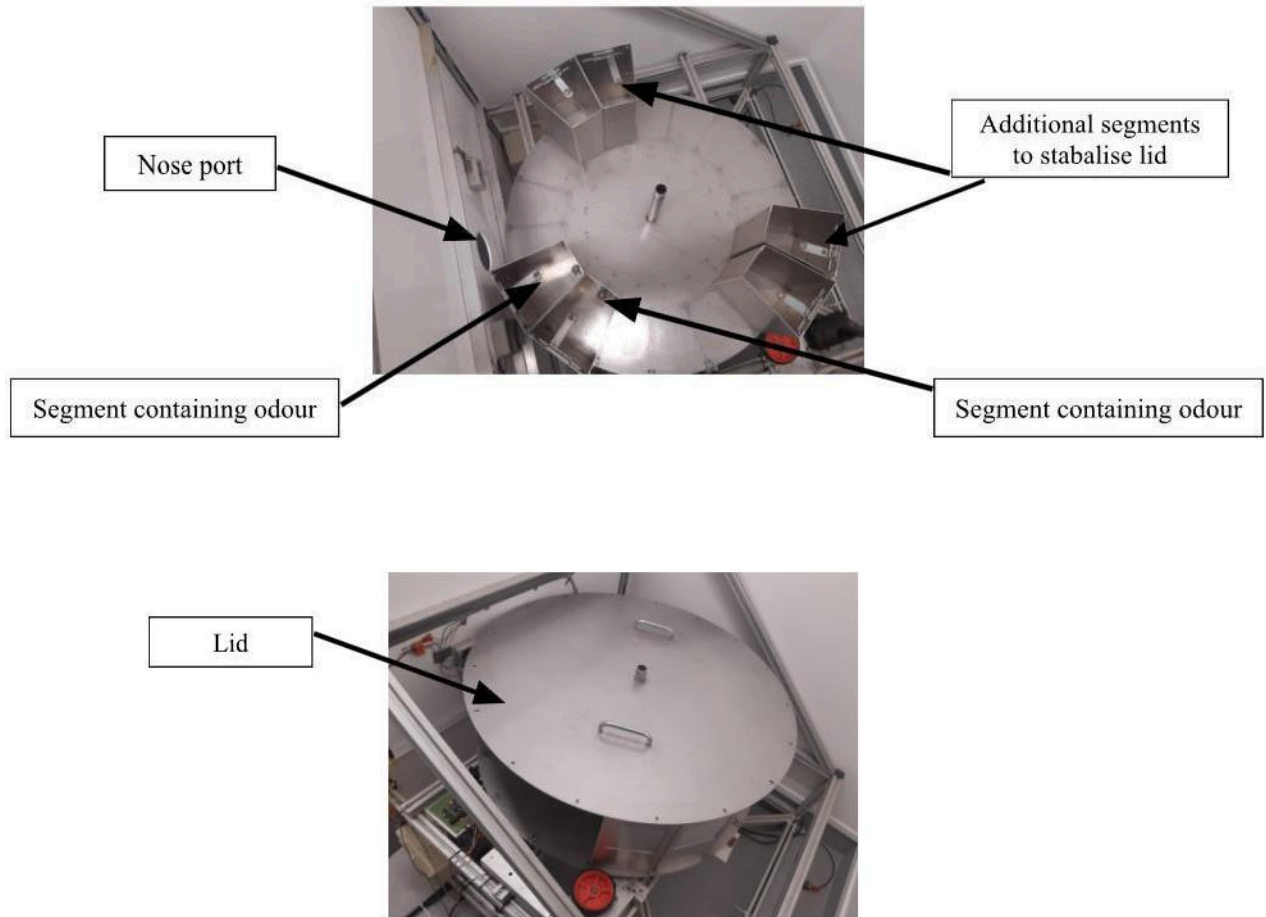
**Equipment**

The equipment used for the current research consisted of a scent delivery carousel, a touch screen and two automated feeders (one for wet food and one for dry food - depending on the dogs' preference). All the equipment was kept inside the experimental room. In the main lab room there were two computers and screens, one which ran the programme to operate the apparatus and record the dog's interactions with the apparatus and touch screen and one with four cameras (located inside the experimental room) connected so the researcher could monitor the dogs when they were alone in the room and record the sessions.

The scent delivery carousel contained 17 spaces for the segments, which could each contain an odour sample. Two segments, placed in positions 1 and 2 on the carousel, contained a predetermined odour sample in a glass vial. A stainless-steel lid (diameter) was placed on top of the segments to keep them in place and seal them, with four empty segments placed on the carousel in positions 6, 7, 12 and 13 to keep the lid balanced (see figure one). Attached to the front of the carousel was an acrylic sheet with a nose port cut out in line with the opening of the segments, to enable the dogs to poke their nose into the segments to sniff the odour (see figure one and two). The scent delivery carousel would emit a short double beep sound when the programme was running, and the carousel had positioned the segment containing the correct scent sample for each trial in front of the port. If the dog inserted their nose into the port whilst it was moving into the correct position, the carousel would stop moving immediately. When the dog inserted their nose into the port, the carousel would emit a consistent beep sound until the dog took their nose out of the port. If the dog inserted their nose into the port before it was ready (e.g. still moving into position), the carousel would not emit the beep noise.

**Figure 1**

*Scent delivery carousel*

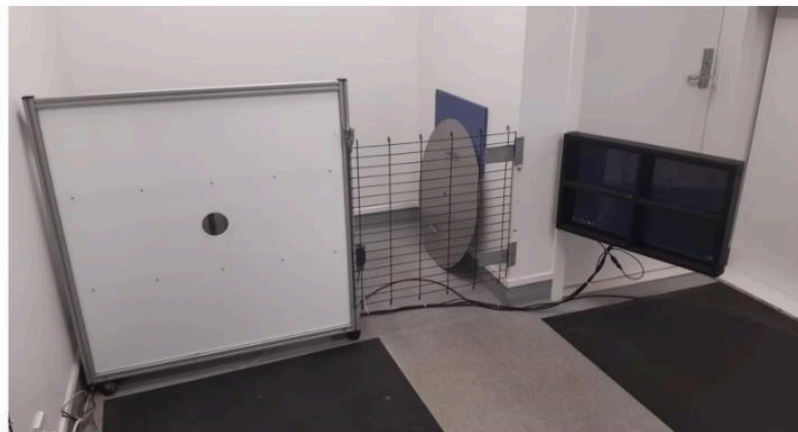


The touch screen was located to the right of the carousel/nose port, attached to the wall on the left side at approximately a 70-degree angle facing the direction of the scent detection apparatus. A computer monitor (model P2714Hc - 1920 x 1080 resolution) was used as a touch screen (model PQ Labs G4 27") and was divided into four sections; top left, top right, bottom left and bottom right, with a black wooden border attached to physically separate the four sections (30cm x 17cm) (see figure three). When activated by the dog poking their nose into the port for the required length of time, two of the four segments remained black and two displayed

the pre-selected images of a black cross/black circle on a white background (see figure three). The programme only responded to the dog's interactions with the two sections containing the images. Nothing happened if the dogs interacted with the two blank sections. Once the dog activated the touch screen by holding their nose in the port and sniffing for the minimum amount of time (1000ms), it would emit a noise to signal the activation. There were also two additional noises, one to signal the dog had indicated the correct image, and one to indicate the dog was incorrect. The positions in which the images appear are randomised each trial by the programme.

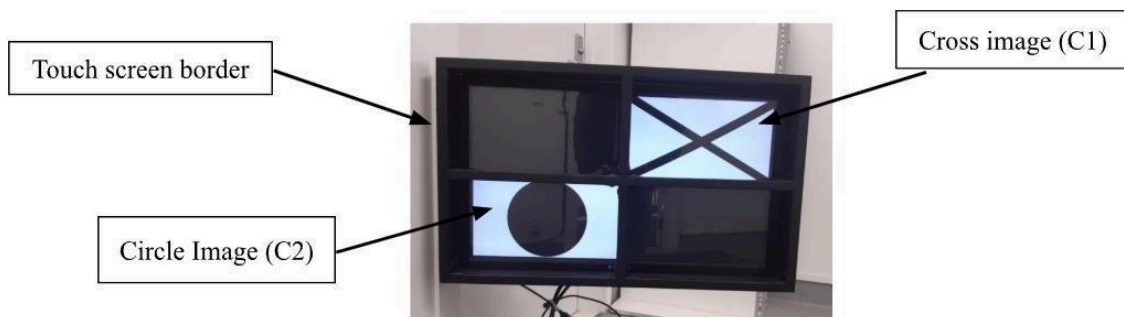
**Figure 2**

*Position of nose port and touch screen in experimental room*



**Figure 3**

*Touch screen with images*



## **Chemicals**

Two chemicals were used during the experiment, linalool, a naturally occurring alcohol scent often found in plants and flowers, and cinnamaldehyde, a naturally occurring flavour found in cinnamon. The chemicals were selected by Campbell-Smith (2024) based on three criteria; 1) distinctive odour, 2) not aversive or harmful to humans or dogs at the concentration used, and 3) previously used in scent detection research with dogs. The chemicals in the concentrated form were stored in a secure laboratory in a fire-proof cabinet. Once prepared by the experimenter, the chemical solutions were clearly labelled and stored in the dog lab fridge. Once used, all chemical solutions were disposed of safely.

## **Solution Preparation**

Solution preparation for the two chemicals took place in the secure laboratory, based on the Solution Preparation Standard Operating Procedure (SOP) (See Appendix A). To prepare the solution, 50 ml of deionised water was measured and poured into a 250 ml Schott bottle. 50  $\mu$ L of the chemical was then added to the deionised water in the Schott bottle and mixed well to combine. Another 50 ml of deionised water was then measured and added to the Schott bottle and mixed well to create 100 ml of the chemical solution. The water-to-chemical concentrate dilution ratio was 2000:1, as this ratio allowed each scent to be recognised by humans, but was low enough that it is unlikely to have been excessive for the dogs. Each bottle was sealed with parafilm before the lid was put on and stored at room temperature for up to two weeks, with new solutions prepared every two weeks.

## **Sample Preparation**

Samples of each of the two chemicals were prepared in the dog lab for each session, based on the Sample Preparation SOP (See Appendix B). Two small glass vials, one for each chemical sample, were used per session. Each vial was labelled with either an “L” for linalool or a “C” for cinnamaldehyde to ensure the correct sample was placed in the correct position on the scent delivery carousel. Each sample consisted of 2 mL extracted from the chemical solution using an autopipette, with the pipette tip changed prior to contact with a new chemical and the autopipette wiped with isopropyl alcohol to prevent any contamination. The vials containing the samples were then placed on the scent delivery carousel in their predetermined positions, segment 1 = linalool and segment 2 = cinnamaldehyde. The carousel was programmed to automatically turn and place the predetermined segment in the space in front of the nose port access for the dog.

## **Training Procedures**

Prior to beginning work with the odours, the new dogs were trained by the researcher in the experimental procedure using operant conditioning. One dog, Indie, did not require any initial behaviour shaping as she was a pre-existing participant from Campbell-Smith’s (2024) research. The target behaviour was for the dogs to poke their nose into the port, opening the flap on the segment housing the odour sample, breaking the beam for 1000ms to activate the touch screen, then using their nose to touch the section of the touch screen containing the shaping image. The initial training involved shaping by successive approximations, which can be defined as reinforcing behaviours that are systematically closer to the desired behaviour until the desired behaviour is achieved (Cooper, Heron & Heward, 2020). This allows for frequent reinforcement

of desired behaviours which increases the likelihood they will occur and over time become closer to the target behaviour until this has been achieved. This also allows for behaviours which are not related to the target behaviour to be placed under extinction conditions, as they are not being reinforced.

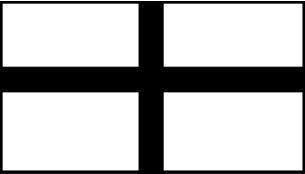
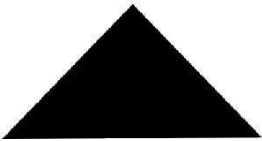
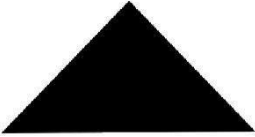
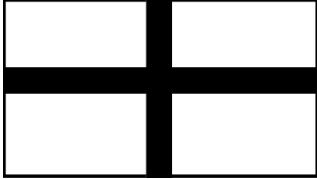
The training procedures were based on the Guidelines for Training Dogs for Scent Detection Work Using Automated Apparatus SOP (See Appendix C). The first part of the training involved shaping the dog's behaviour of poking their nose into the nose port attached to the scent delivery carousel. The target behaviour for the nose port/scent delivery carousel was for the dog to poke their nose into the port to open the flap on the segment (which would house the odour sample) and holding their nose inside the port for at least 1000ms, the minimum threshold needed to activate the touch screen. Once the dog was reliably performing the target behaviour, they were then trained to interact with the touch screen. The target behaviour for the touch screen was for the dog to reliably touch the shaping image on the touch screen with their nose, regardless of which quadrant the image appeared in on the screen, demonstrating stimulus control, as opposed to simply touching the screen.

Once the dog was reliably touching the shaping image on the touch screen, the dogs were then introduced to a simple visual discrimination task in order to train the dogs to engage in simple image discrimination. No odours were included in this task, the dogs were only interacting with the touch screen. Ralph, Gizzy, Tessa and Tilly were introduced to the simple discrimination task as part of their training. As Indie was a previous participant, she was taken off the odour discrimination task temporarily to participate in the simple discrimination task. Indie had not been previously trained to do this as it was not part of the previous methods used by Campbell-Smith (2024). The simple visual discrimination task had two stages and consisted

of two black and white images, a plus and a triangle (see table one), appearing on the touch screen simultaneously in randomised positions for 15 trials per session. During the first stage, the plus sign was always correct, and the triangle was always incorrect, to assess whether the dogs could demonstrate stimulus control of the selection response by these shapes. The criteria for passing the first stage were for the dog to respond correctly in at least 12/15 trials (80% accuracy threshold) three sessions in a row. Once a dog met these criteria, they progressed to the second stage of the simple visual discrimination, whereby the triangle was always correct and the plus was always incorrect, to expose the dogs to a reversal of the SD and S-delta to evaluate the establishment of stimulus control and demonstrate reversal learning. The passing criteria for the second stage was the same as the first stage.

**Table 2**

*Simple visual discrimination images*

Stage one	S+		S <sup>Δ</sup>	
Stage two	S+		S <sup>Δ</sup>	

Once a dog had successfully completed the simple visual discrimination task, they then entered the last phase of training, which involved another operant conditioning technique known as chaining, defined as the process of teaching complex behaviours by breaking them down into smaller steps, then linking them in a chain by sequential order until the target behaviour can be

performed in its entirety (Martin & Pear, 2015). The dogs had learned each step of the target behaviour during shaping, to poke their nose into the port to open the flap on the segment to break beam for at least 1000ms and touch the image on the touch screen with their nose, then go to the feeder for reinforcement when they hear the sound. The last step of training was for the dog to do all the behaviours in a sequential behaviour chain, first the port/segment, then the touch screen, then the reinforcement feeder. The activation of the screen with the presence of the image(s) functioned as a conditioned reinforcer for poking their nose into the port and a discriminative stimulus for interacting with the screen. The dog was minimally prompted when necessary to go to the port and/or the screen by the researcher. Once the dog was able to complete the behaviour chain reliably without the researcher present in the room, they then began to work with the odours.

## **Experimental Procedures**

After completing training, the dogs then started the conditional discrimination (CD) task, where they were required to discriminate between two odours by indicating which odour they were smelling using images of shapes, which have been arbitrarily matched to each odour by the experimenter, the identical pairings used by Campbell-Smith (2024). In the presence of the C1 odour (linalool), choosing the cross image (see table two) was reinforced, and in the presence of the C2 odour (cinnamaldehyde), choosing the circle image (see table two) was reinforced. If the dog chose the incorrect shape (e.g. the circle in the presence of C1), a correction procedure was implemented whereby the dog repeated the identical trial (same odour and the images reappear on the screen in the same positions) until they chose the correct shape. When the dog chose correctly, they were immediately reinforced. Each session had a minimum of 15 trials, more depending on how many repetitions are required due to the correction procedure. Each dog


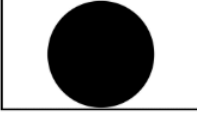














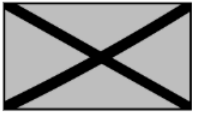



completed between four and eight sessions each time they were in the lab, depending on the time spent in the lab and how many dogs were present during the session. One dog, Indie, completed 139 sessions of CD using trial and error procedures before starting the simple visual discrimination task and doing the CD task with an errorless learning procedure added. Once Indie completed simple visual discrimination and Ralph, Tessa and Tilly passed the chaining stage of training after simple visual discrimination (Gizzy did not pass the chaining stage), they began the conditional discrimination task with an errorless learning procedure (ELP) included. The ELP consisted of reducing the brightness of the incorrect image (S-) in each trial, while always keeping the correct image (S+) at 100% brightness. We started with a low level of brightness (25%) then increased the brightness each time the dog responded correctly in at least 80% of trials for both odour, three sessions in a row (mastery criteria). The experimental procedures for the conditional discrimination task were the same with and without the errorless learning procedure added.

The reduced brightness images were created using PaintShopPro 7©, where copies of the original cross and circle images were made with the brightness reduced for each of the successive levels (25%, 37%, 50%, 63% and 75% - as shown in table two). This was done by opening the original image at 100% brightness in PaintShopPro 7© and adding a new layer onto the image. We then clicked on “adjust” and in the drop-down menu and found “brightness and contrast” and on the brightness slider, then moved the slider to the left until it was pointing to the correct number (e.g. 25) to reduce the brightness of this new layer to the desired level (e.g. 25%). We then saved a copy of this reduced brightness image (e.g. Cross25).

Initially we increased the brightness by 25% each time the dog met the mastery criteria (25%, 50%, 75%) then adjusted the procedure to add intermediate levels (37% and 63%) in

response to the first two dogs (Indie and Ralph) who attempted conditional discrimination with the ELP not meeting the mastery criteria when they reached the higher levels of brightness (50% and 75% respectively). We also then added termination criteria to the procedure, whereby if a dog did not pass the level of brightness, they were on within 30 sessions, they would go back to the previous level where they were last successful. Once they passed that level again, they would go back up to the previously unsuccessful level for a second attempt. If the dog did not pass this level on their second attempt within 30 sessions, their conditional discrimination sessions with the ELP would be terminated. None of the dogs successfully completed every level of the ELP, all were terminated at either 50% (Indie) or 75% (Ralph, Tessa & Tilly). Once Indie met termination criteria for the CD task with the errorless learning procedure, she did not complete any more CD sessions without the ELP due to time constraints. Ralph, Tessa and Tilly were able to complete some conditional discrimination sessions without the ELP (55, 42 and 30 sessions respectively) after they met termination criteria on the CD task with the ELP, but not as many as Indie due to time constraints.

**Table 3***Errorless learning procedure (ELP) images*

Brightness level	S+ Circle	S+ Cross
25%	 	 
37%	 	 
50%	 	 
67%	 	 
75%	 	 

**Data Analysis**

Data were automatically collected from each dog for every session they did, using both a computer programme and physical data sheets (one for each day/each dog) where the researcher kept a tally of correct/incorrect responses for each trial and percentages of total correct responses for each odour/shape pairing. The data collected using the physical data sheets was then graphed regularly to monitor progress in the form of line graphs. The final data for each of the different parts of the experiment were graphed separately using excel. Statistical analysis was conducted

using SPSS. Means and standard deviations were analysed for the CD task, both with and without the ELP. 95% binomial confidence intervals were also calculated for the CD task without the ELP. Screen quadrant and shape bias data, as well as a comparison of the dogs' sniff and response times were also analysed using SPSS and graphed in excel.

## Chapter 3

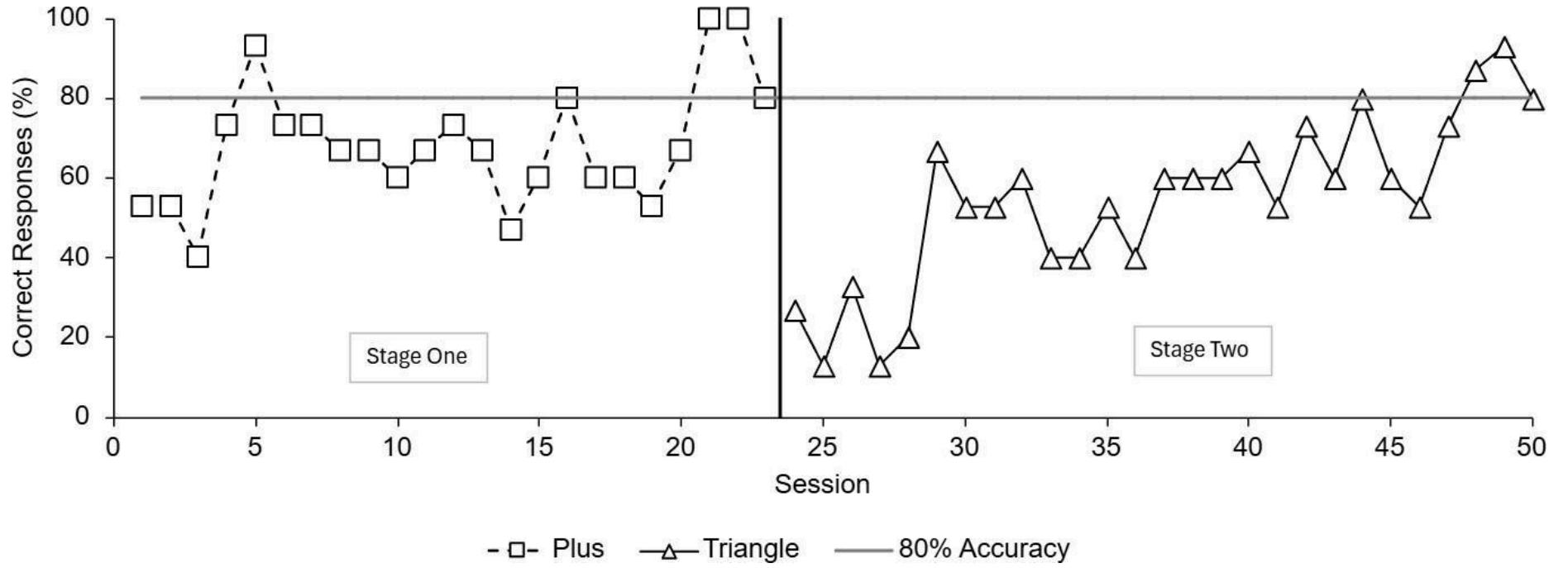
### Results

#### Simple Visual Discrimination

All five dogs participated in the simple visual discrimination (SVD) task. There was some variability in how long each dog took to meet the mastery criteria for each shape, but all five dogs ultimately met the mastery criteria of 80% accuracy for three consecutive sessions for both stage one (S+ plus) and stage two (S+ triangle). Indie completed the SVD task in the least number of sessions (50) and took almost the same number of sessions to complete each stage (stage one = 23, stage two = 27). Ralph completed the SVD task in 61 sessions and completed stage one a lot quicker than stage two (stage one = 12, stage two = 49). Tessa completed the SVD task almost as quickly as Ralph, in 62 sessions and was also a lot faster on stage one than stage two (stage one = 17, stage two = 45). Tilly completed the SVD task in 66 sessions and took almost the same number of sessions as Indie to complete stage one but was slower to complete stage two (stage one = 23, stage two = 43). Gizzy took the longest to complete the SVD task with 74 sessions and was also a lot quicker with stage one than stage two (stage one = 25, stage two 49).

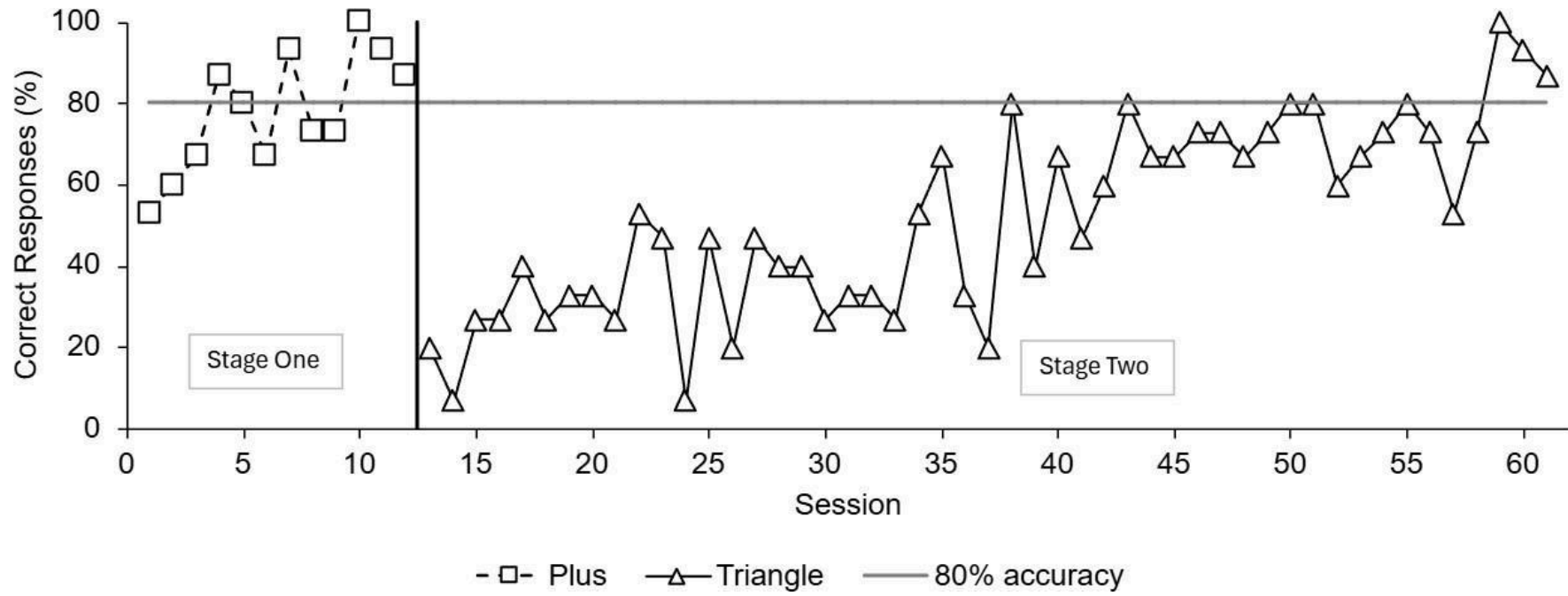
**Figure 4**

*Indie's Simple Visual Discrimination Data*



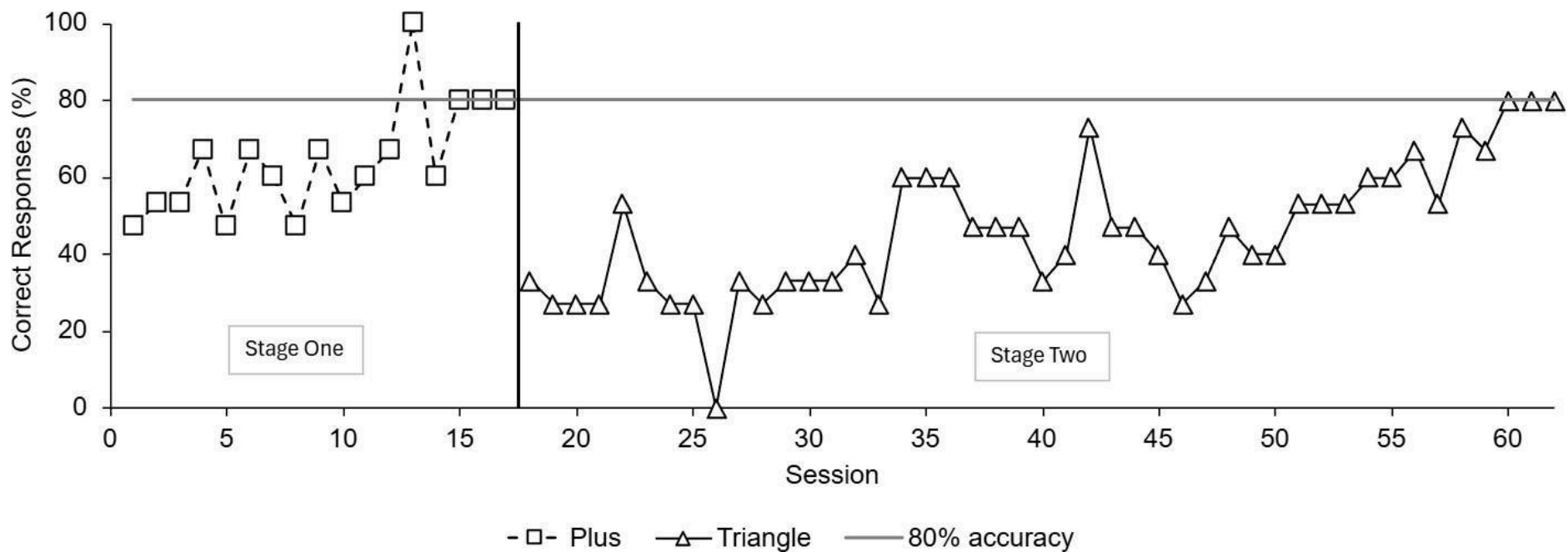
**Figure 5**

*Ralph's Simple Visual Discrimination Data*



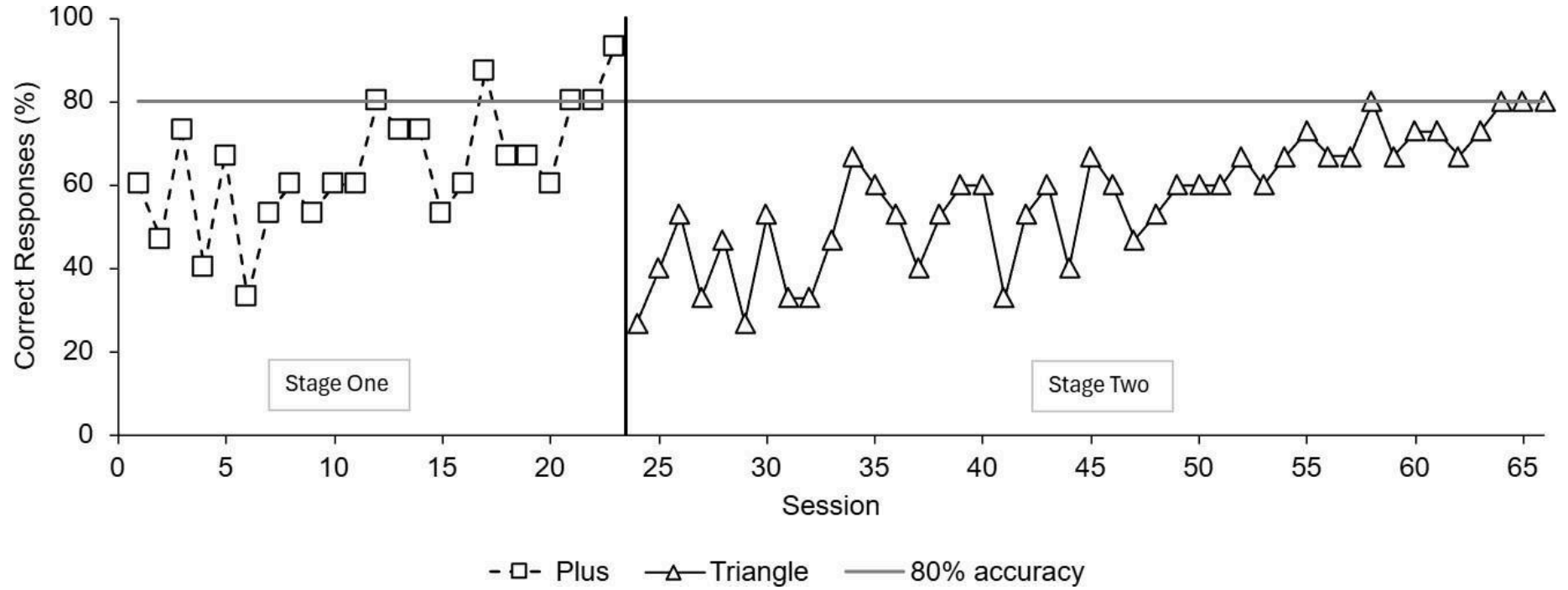
**Figure 6**

*Tessa's Simple Visual Discrimination Data*



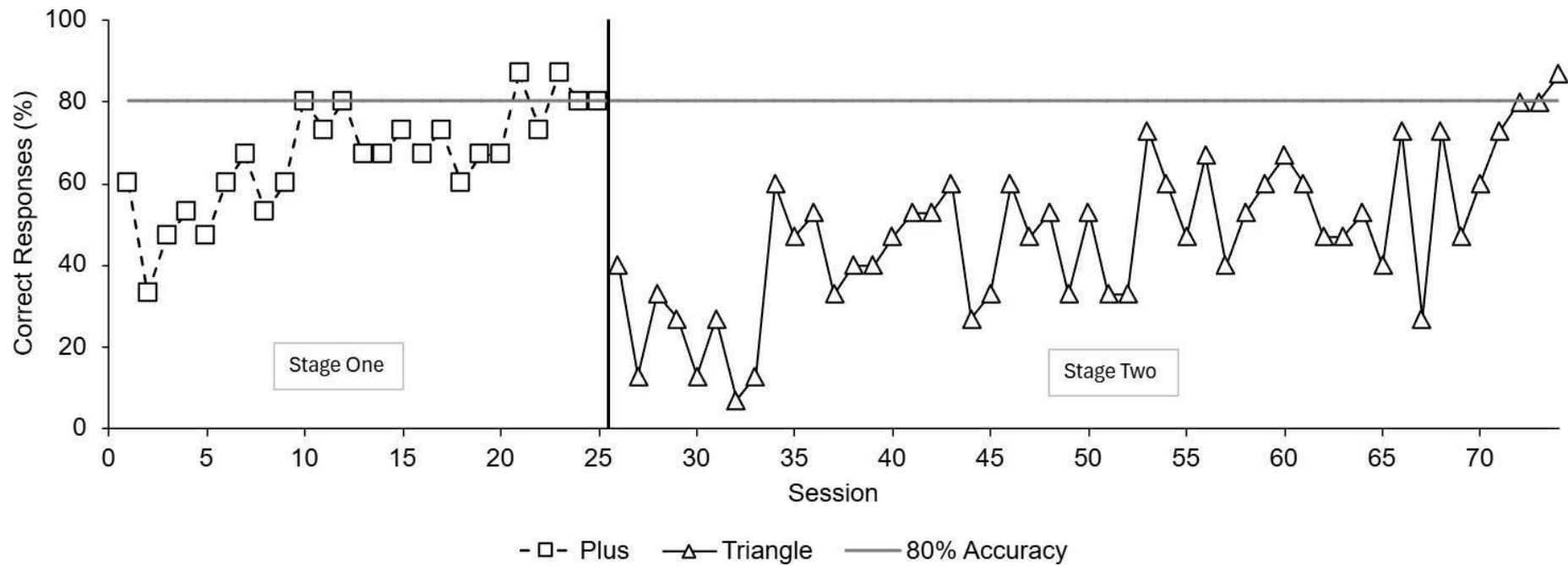
**Figure 7**

*Tilly's Simple Visual Discrimination Data*



**Figure 8**

*Gizzy's Simple Visual Discrimination Data*



## **Conditional Discrimination Task with Errorless Learning Procedure**

Indie, Tessa, Tilly and Ralph participated in the conditional discrimination (CD) task with the errorless learning procedure (ELP). Indie and Ralph began the CD task with the ELP first, and started at 25% opacity, both then progressed to 50% after meeting criteria, with Ralph also progressing to 75%. After several sessions each, Indie had not met criteria for 50% and Ralph had not met mastery criteria for 75%. This prompted a discussion on the difference between the respective levels of errorless learning (25%, 50% and 75%) and led to the addition of intermediate levels (37% and 63%) to see if more steady progression increased response accuracy. Indie then went back to 37% (intermediate level between 25% and 50%) and Ralph went back to 63% (intermediate level between 50% and 75%). Once Indie and Ralph each passed their respective intermediate levels, they then had a second attempt at the higher levels where they were previously unsuccessful (Indie at 50% and Ralph at 75%). They each had 30 sessions to meet the mastery criteria and progress to the next highest level (termination criteria), both were unsuccessful (see figures 9 and 10 below).

Due to missed sessions, Tessa and Tilly began the CD task with the ELP later than Indie and Ralph, after the intermediate levels and termination criteria had already been added. Tessa and Tilly progressed through each ELP level successively (25%, 37%, 50%, 63% and 75%). Both were unsuccessful at their first attempt on 75% (i.e. did not meet mastery criteria within 30 sessions) so went back to 63% then, once they met mastery criteria for 63%, had a second attempt to pass 75% within 30 sessions (termination criteria) both were unsuccessful (see figures 11 and 12 below). Of note however, is that Tessa and Tilly did progress through each level or errorless learning in fewer sessions than Indie and Ralph.

We also compared the descriptive statistics for the first and second attempts of each dog at the level of ELP where they were unsuccessful (50% for Indie and 75% for Ralph, Tessa and Tilly) to examine whether the dogs were responding, on average, at above chance accuracy (50%) and to see if the dogs were more accurate on their second attempt, despite not meeting the 80% mastery criteria (see table three below).

**Table 4**

*Comparison of descriptive statistics for dogs' first and second attempt on unsuccessful ELP level*

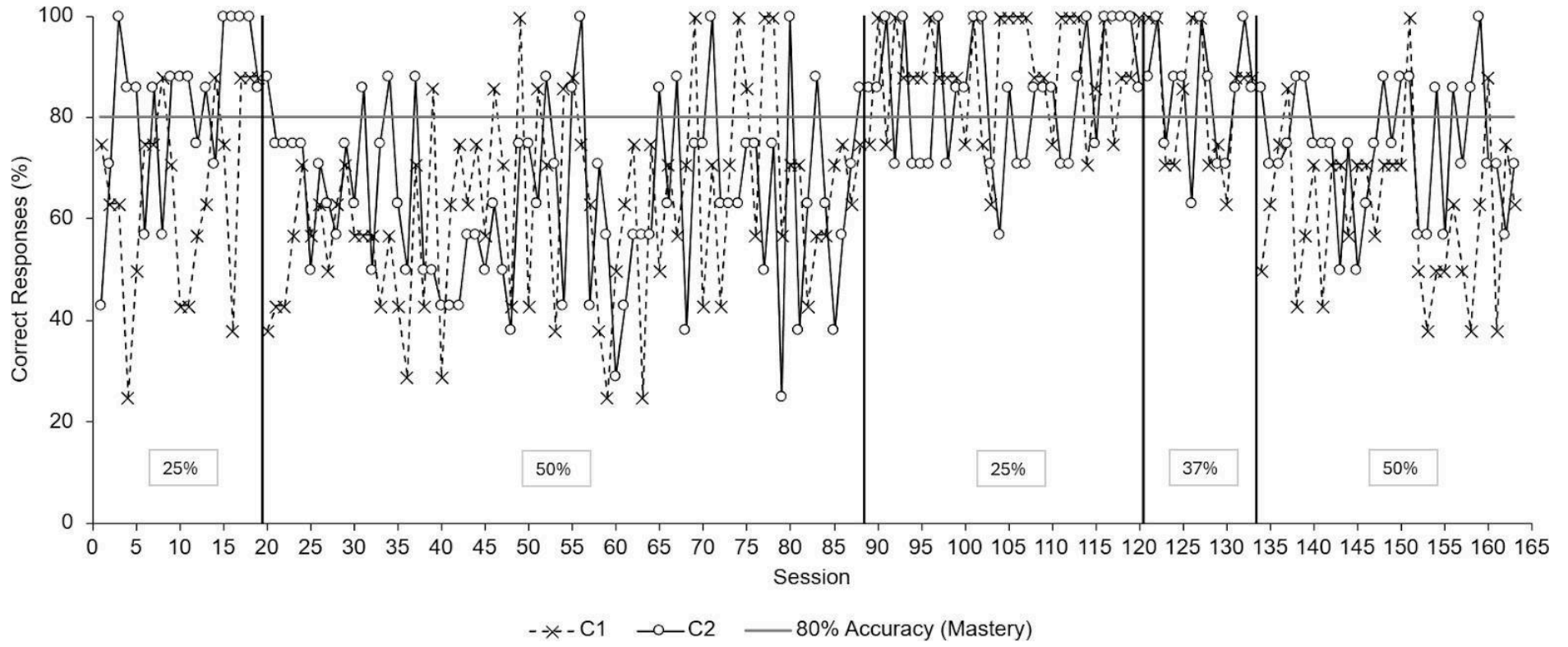
Dog	ELP level	Odour	First attempt <i>M, SD</i>	Second attempt <i>M, SD</i>
Indie	50%	C1	<i>62.6, 18.7</i>	<i>62.2, 15.4</i>
		C2	<i>64.4, 17.6</i>	<i>74.2, 12.8</i>
Ralph	75%	C1	<i>56.9, 16.9</i>	<i>67.9, 17.1</i>
		C2	<i>57.4, 17.2</i>	<i>66.5, 15.1</i>
Tessa	75%	C1	<i>65.9, 14.6</i>	<i>73.2, 18.4</i>
		C2	<i>58.9, 18.2</i>	<i>61.7, 14.9</i>
Tilly	75%	C1	<i>70.0, 14.8</i>	<i>75.6, 15.8</i>
		C2	<i>67.2, 18.3</i>	<i>66.9, 16.5</i>

Indie was above chance (50%) for both C1 and C2 on her first and second attempts at 50%. Indie was also more accurate overall on her second attempt for C2 but had almost the same accuracy for both attempts for C1, with less variability on the second attempt for both odours. Ralph was also above chance (50%) for both attempts at 75% for both C1 and C2, however unlike Indie, he was more accurate overall on his second attempt. Ralph had slightly more variability for his second attempt with C1 and less variability on his second attempt for C2. Like Ralph, Tessa was above chance (50%) for both C1 and C2 for her first and second attempts at

75% and was also more accurate overall on her second attempt with more variability for C1 and less variability for C2. Tilly was also above chance (50%) for C1 and C2 for both attempts at 75%, although she was more accurate on the second attempt for C1 with more variability and slightly less accurate on her second attempt for C2 with less variability.

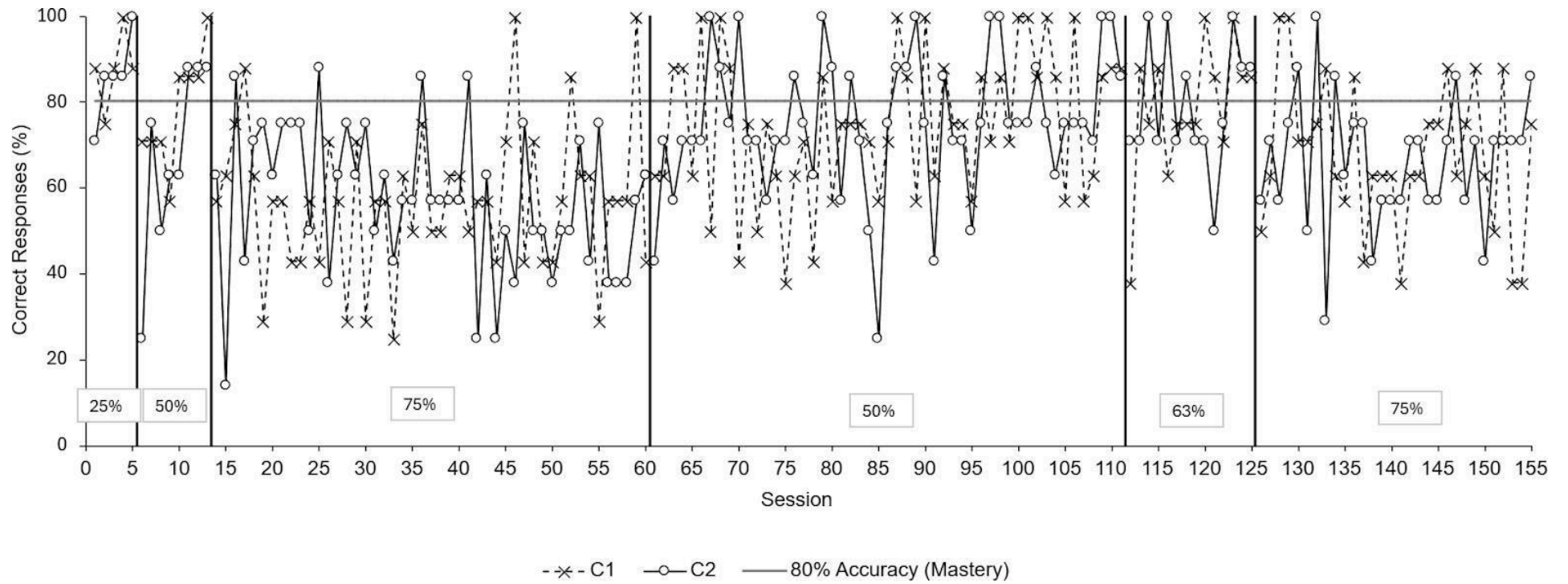
**Figure 9**

*Indie CD task with ELP Data*



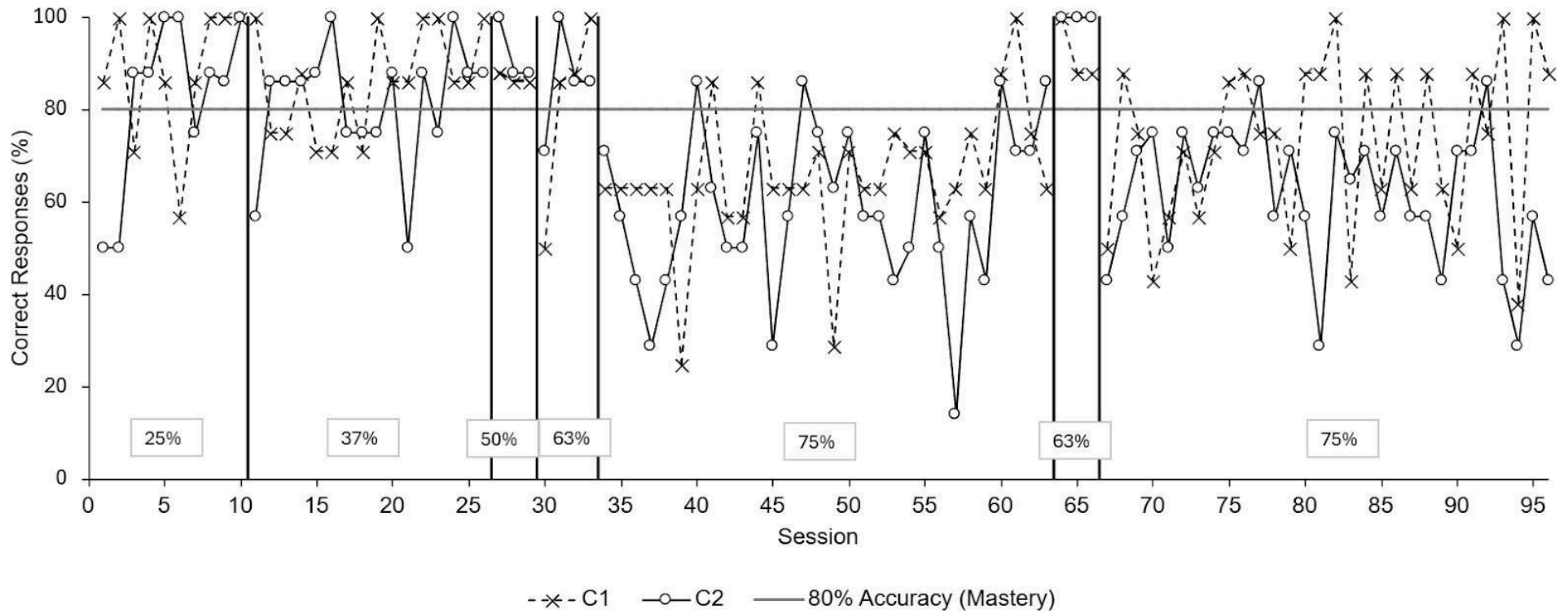
**Figure 10**

*Ralph CD task with ELP Data*



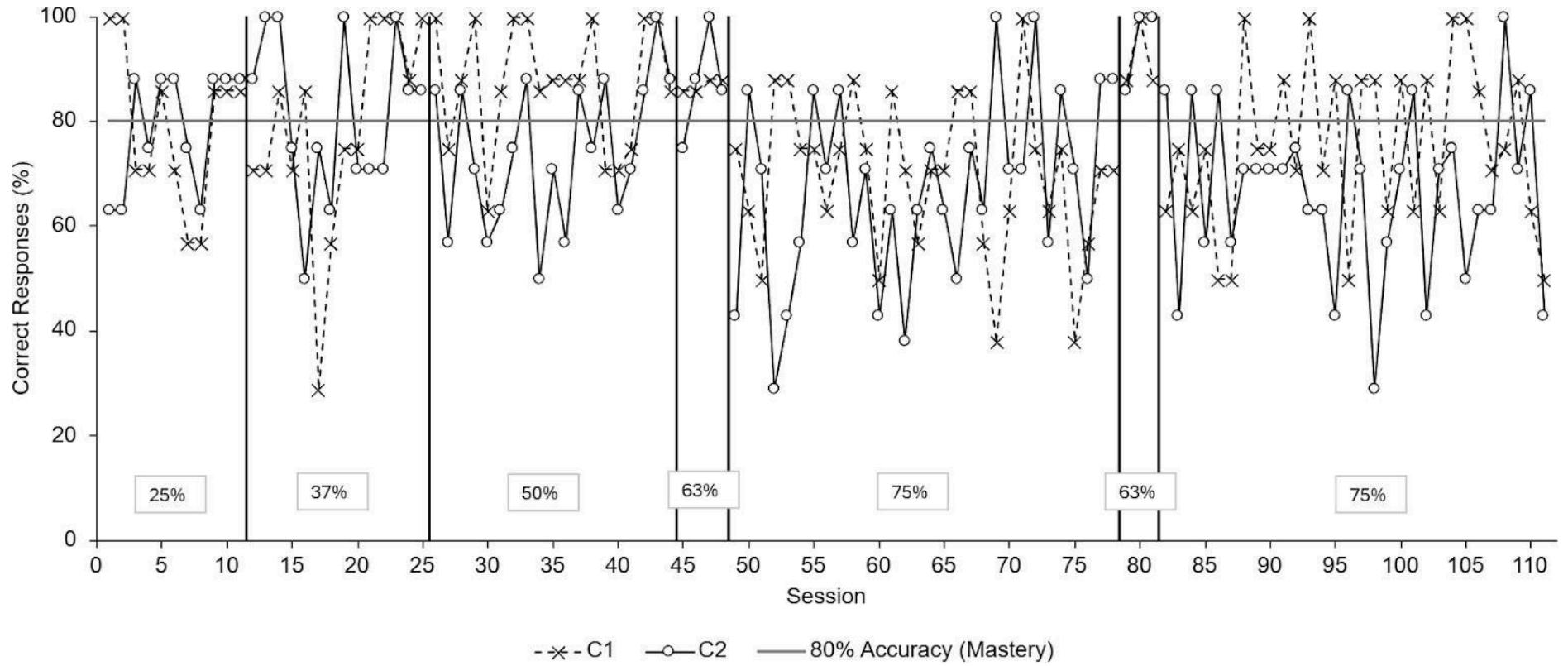
**Figure 11**

*Tessa CD task with ELP Data*



**Figure 12**

*Tilly CD task with ELP Data*



### **Conditional Discrimination Task Without Errorless Learning Procedure (ELP)**

Figures 13, 14, 15 and 16 below show the percentage of correct responses each dog gave for each of the two odours, C1 and C2. Overall, the dogs were responding at or above chance accuracy for one or both odours, all with high levels of variability from session to session. Indie was the only dog who completed her conditional discrimination sessions prior to the addition of the errorless learning procedure. Although Indie had consistent attendance and completed between six and ten sessions per day, she showed considerable variability for both odours and was more accurate overall for C2 ( $M = 52.13$ ,  $SD = 19.27$ ) than C1 ( $M = 42.41$ ,  $SD = 17.39$ ).

Ralph, Tessa and Tilly all completed conditional discrimination sessions after passing shaping, simple visual discrimination, chaining and reaching termination criteria on 75% of the CD task with the ELP. Ralph completed the most sessions out of the three dogs but also had a high rate of variability in his responding, achieving the lowest rate of correct responding for C1 ( $M = 49.82$ ,  $SD = 16.27$ ) while his accuracy for C2 was right on 50% overall ( $M = 50.03$ ,  $SD = 17.61$ ). Tessa and Tilly both missed sessions throughout the year due to their owners travelling (they had the same owners) missing Mondays and Tuesdays every two or three weeks. Tessa was the most accurate overall for C1 ( $M = 62.15$ ,  $SD = 16.22$ ) and the least accurate overall for C2 ( $M = 41.44$ ,  $SD = 18.67$ ), and was highly variable for both odours, often starting a day with a higher accuracy session then gradually declining over the rest of her sessions on the same day. Despite also showing considerable variability, Tilly had overall the second highest accuracy for C1 ( $M = 52.13$ ,  $SD = 17.63$ ) and the highest accuracy for C2 ( $M = 59.33$ ,  $SD = 18.45$ ). Tilly completed the least amount of sessions out of the four dogs on the conditional discrimination task due to a lack of time for data collection and missing sessions.

Table four shows the 95% binomial confidence intervals for each dog's accuracy rates overall. The 95% CI lower and upper bounds show the range in which we can be 95% confident the true success rate exists. The accuracy rates did not overlap with 50% for all four dogs, as each of them had an accuracy range higher than 50% with significant p-values (see table four). Ralph had the highest overall range with [.57, .62] and Tessa had the second highest overall range with [.55, .61]. Indie had the lowest overall range with [.53, .56]. As Tilly completed the least amount of sessions, she had the widest range with [.52, .69]. These results suggest that all dogs were responding at above chance (50%) accuracy overall, which provides support for the first hypothesis.

**Table 5**

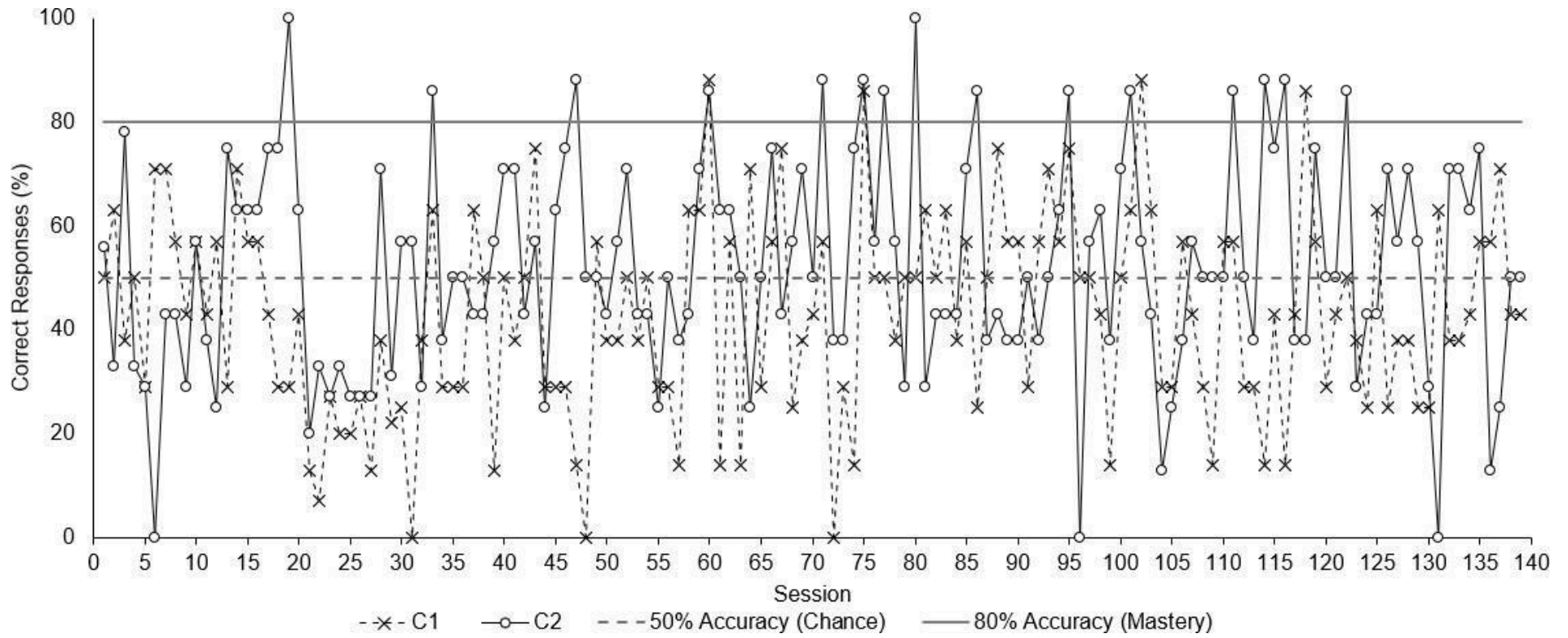
*95% binomial confidence intervals for dogs' overall accuracy on the CD task without the ELP*

	95% CI Lower Bound	95% CI Upper Bound	Sample Estimate	p-value
Indie	.53	.56	.55	<.001
Ralph	.57	.62	.60	<.001
Tessa	.55	.61	.58	.002
Tilly	.52	.59	.56	<.001

*Note.* Null Probability = .5

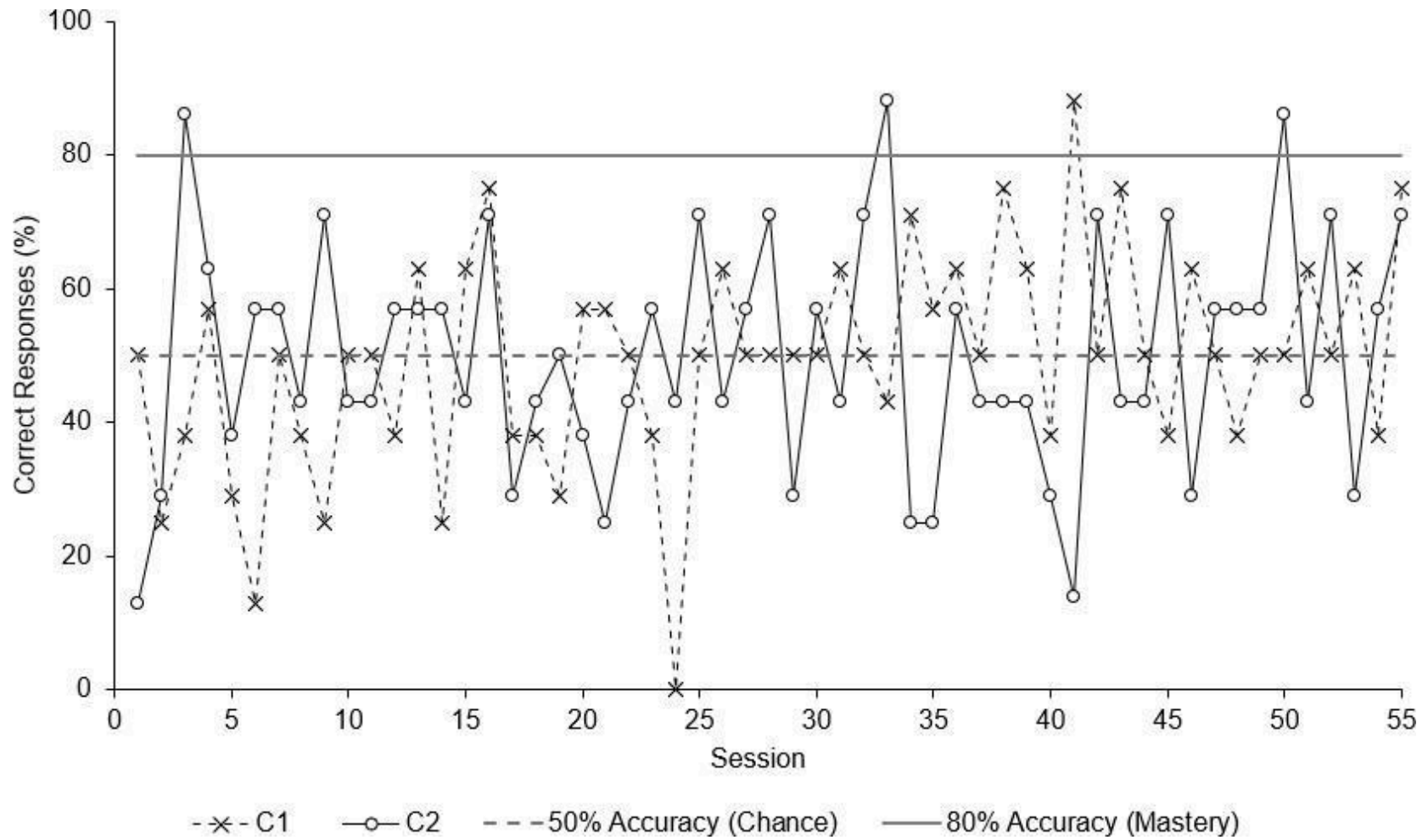
**Figure 13**

*Indie Conditional Discrimination Data*



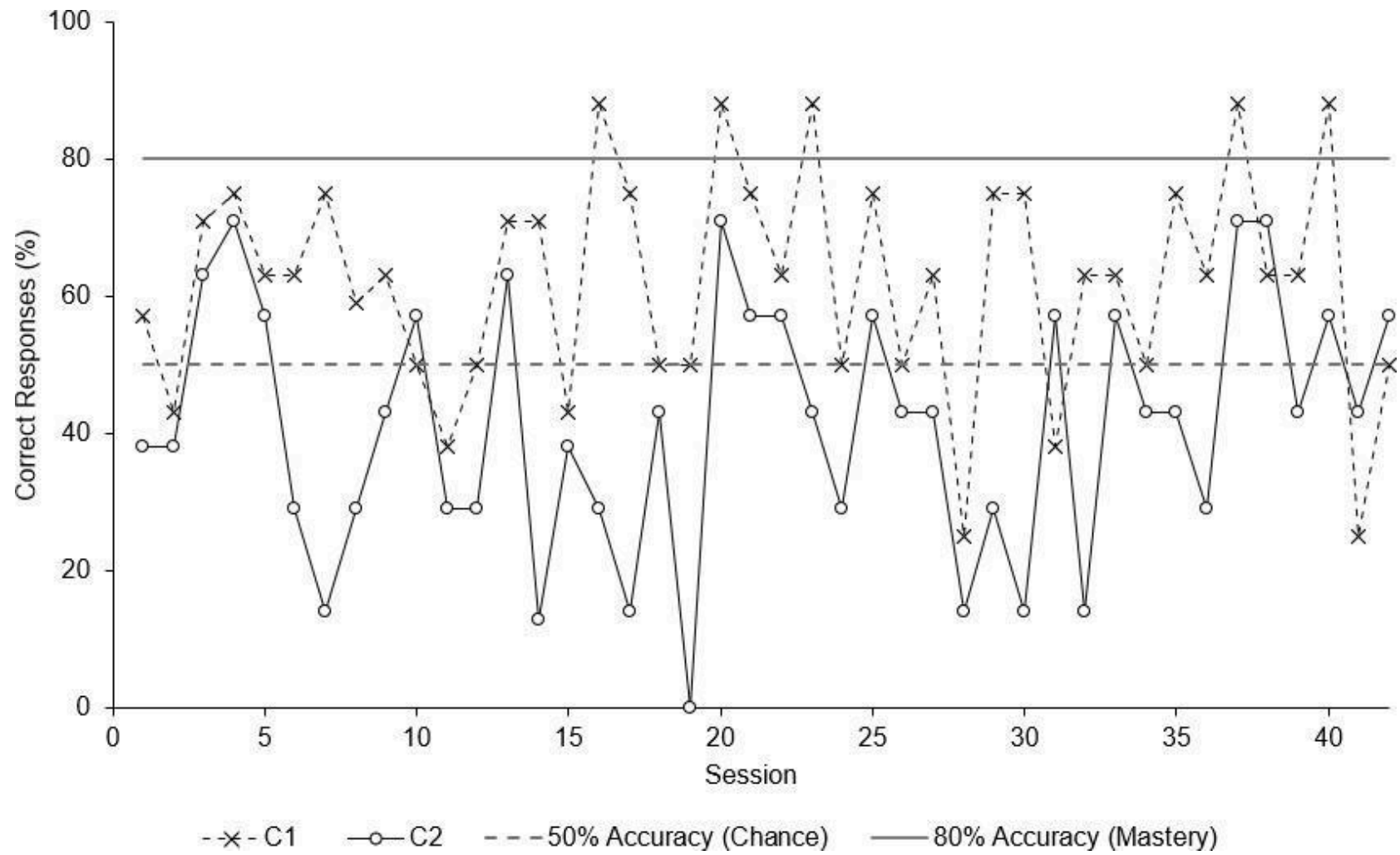
**Figure 14**

*Ralph Conditional Discrimination Data*



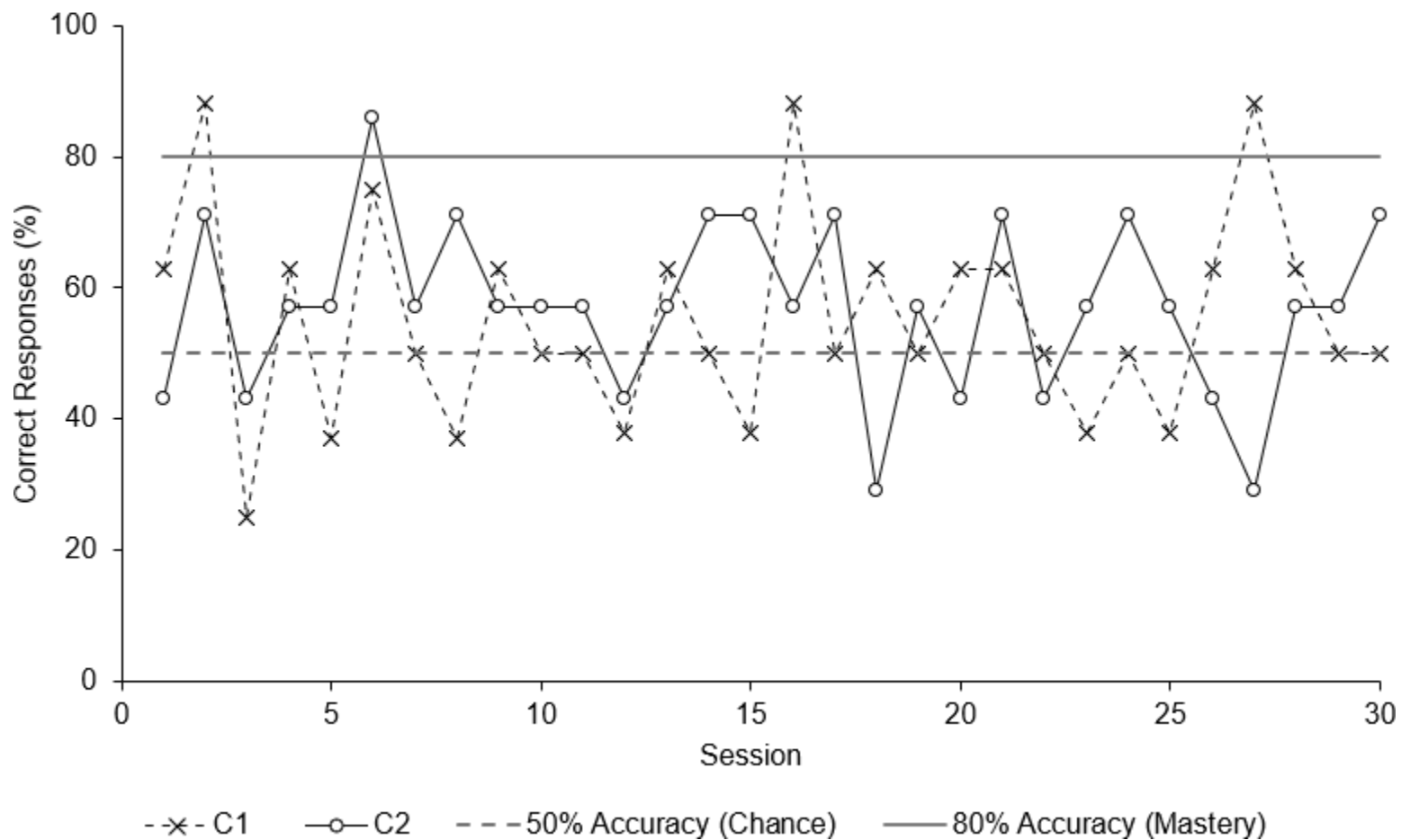
**Figure 15**

*Tessa Conditional Discrimination Data*



**Figure 16**

*Tilly Conditional Discrimination Data*

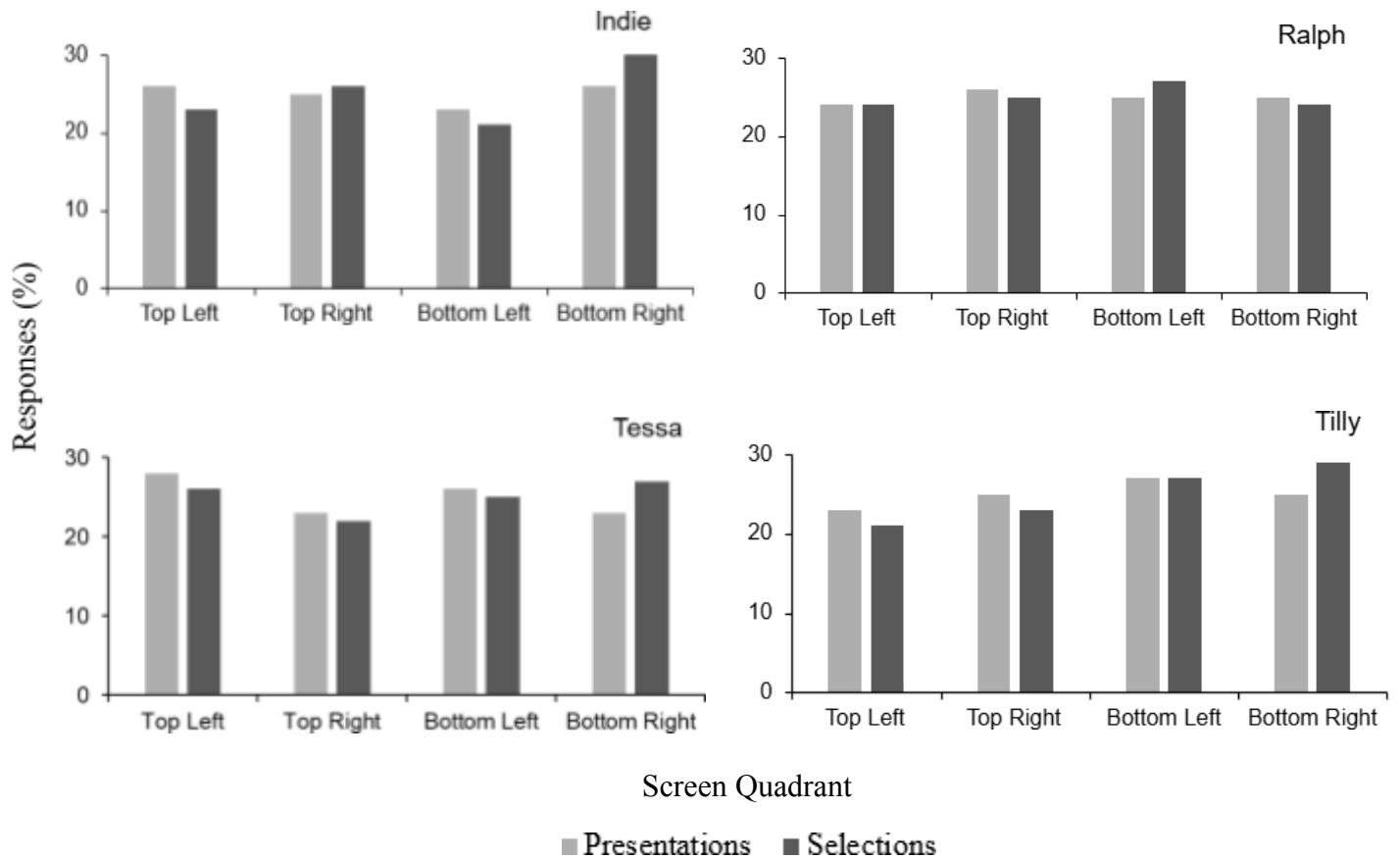


## **Quadrant Position Bias**

The comparison of how many times each shape appeared in each of the four quadrants on the screen and how many times the dogs chose each quadrant suggests that none of the dogs showed any strong bias towards any one quadrant during the conditional discrimination task (without the ELP) (see Figure 17). The responses each dog made to each quadrant were largely proportional to the number of times an image appeared in each quadrant. While Indie, Tessa and Tilly did choose the bottom right quadrant more than the other three quadrants, the percentage of responses to the bottom right quadrant were within 4%, 1% and 2% respectively of their next most preferred quadrant, which is not a big enough difference to have an impact on the responding.

**Figure 17**

*Comparison of shape presentations and selections in each touch screen quadrant*



*Note: "Shape presentations" refers to the number of times a shape was presented as the correct choice in that quadrant and "selections" refers to the number of times the dog selected a shape in that quadrant*

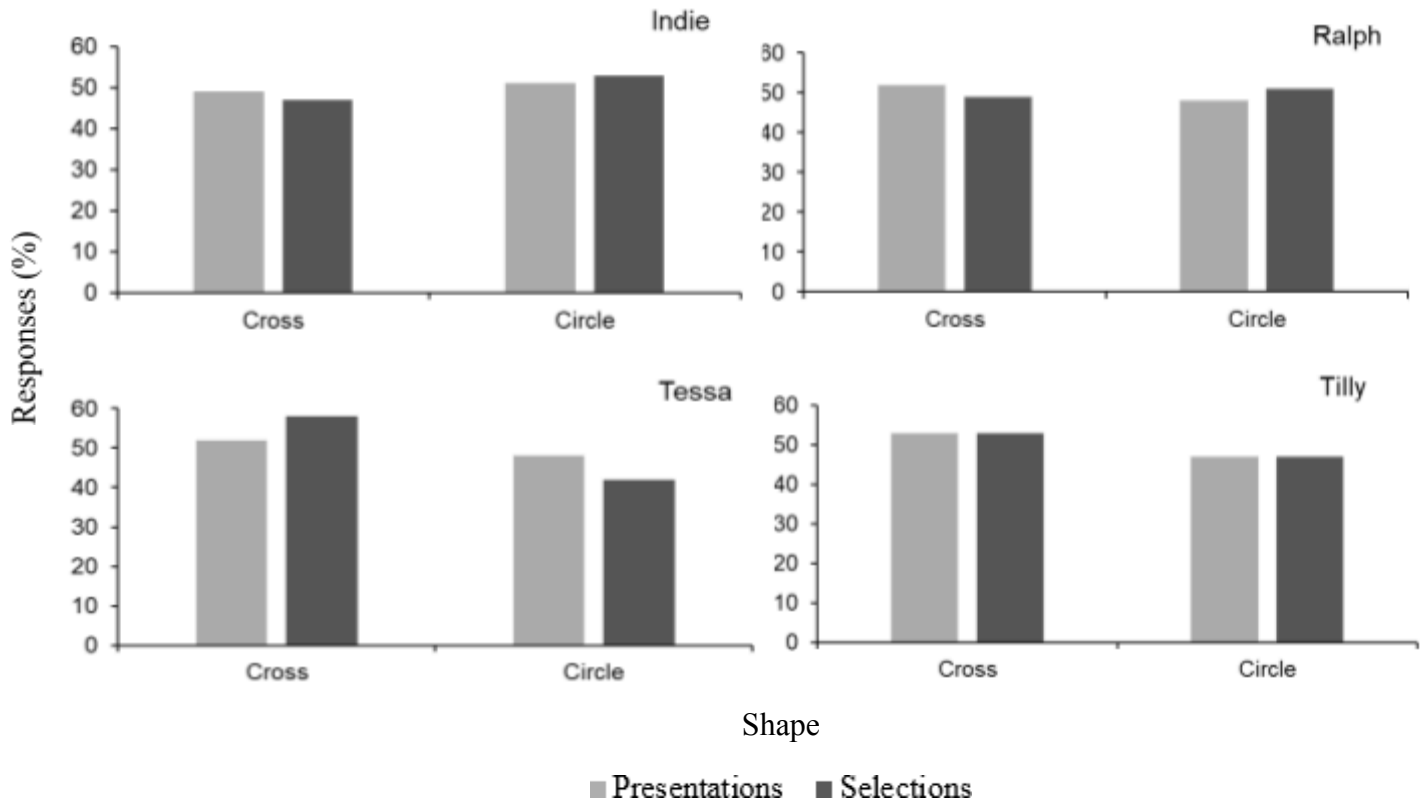
### **Shape Bias**

To evaluate the presence or absence of shape bias in the dogs, we compared how many times each shape appeared as the correct choice in any of the four quadrants on the screen and

how many times the dogs chose each shape (either correctly or incorrectly) during the conditional discrimination task (without the ELP). This comparison showed that only one dog, Tessa, had a strong bias towards the cross, choosing the cross 16% more than the circle (58% versus 42%) even though it was presented only 4% more often (52% versus 48%); (see figure 17). This could explain why Tessa's mean accuracy was much higher for C1 (62.15) than for C2 (41.44) on the CD task without the ELP. By contrast, Ralph chose the circle only 3% more than the cross and Indie chose the circle only 5% more than the cross. As there were 15 trials per session, it was always split so one shape would be correct seven out of 15 trials, and the other would be correct eight out of 15 trials. As the order and division of presentations was electronically randomised every three-four sessions, one shape may have been presented as correct at a slightly higher frequency than the other for each dog, depending on the randomisation. For Indie, the circle was presented slightly more often than the cross (51% compared to 49%), which could explain why she chose the circle more often. For Ralph however, the circle was presented slightly less than the cross, (48% compared to 52%) so his choosing the circle more often despite it being presented less frequently could indicate a slight bias towards the circle. Interestingly, the percentages of Tilly's selections of the cross and the circle were exactly the same as the percentage of presentations for each shape (53% for cross and 47% for circle).

**Figure 18**

*Comparison of shape presentations and shape selections*



*Note: “Shape presentations” refers to the number of times a shape was presented as the correct choice and “selections” refers to the number of times the dog selected each shape (correctly or incorrectly)*

### **Sniff time and response time**

Sniff time (ms) refers to the length of time the dog had their nose inserted into the port of the scent delivery carousel sniffing the odour for each trial of the conditional discrimination task (without the ELP). Response time (ms) refers to the time between the dog taking their nose out of the port and selecting a shape on the touch screen. We compared both the average sniff times

and average response times for each dog, divided into the different types of responses they could give each trial (see table five), as we were interested in whether the length of sniff and time delay between contact with the odour and selecting an image had any effect on the dog's accuracy of responding. As shown in table six, the average sniff times and response times are consistent for each individual dog across all response types, with no noteworthy difference for either sniff time or response time based on the response type.

It is worth noting however that Tilly had the longest average sniff times across all response types but was the third most accurate overall on the CD without the ELP (see table four). Indie had the shortest average sniff time and was the least accurate overall on the CD task without the ELP. Interestingly, Tilly also had the longest average response times and Indie again had the shortest average response times across all types of responses. Tessa had the greatest difference in mean accuracy, being far more accurate on C1 ( $M = 62.15$ ) than C2 ( $M = 41.44$ ), however there was almost no difference between any of her average sniff times and average response times across response types. These results suggest that the length of sniff and time delay between sniffing the odour and selection of an image did not have an effect on the dog's responding accuracy.

**Table 6***Sniff time and response time for each response type (ms)*

		Cross Correct <i>M, SD</i>	Circle Correct <i>M, SD</i>	Cross Incorrect <i>M, SD</i>	Circle Incorrect <i>M, SD</i>
Indie	Sniff time	1157, 254	1155, 203	1172, 243	1156, 226
	Response time	1723, 629	1741, 663	1713, 644	1714, 637
Ralph	Sniff time	1250, 312	1228, 334	1233, 327	1233, 342
	Response time	2196, 594	2205, 678	2209, 654	2202, 645
Tessa	Sniff time	1472, 399	1437, 394	1464, 410	1483, 422
	Response time	2055, 546	2080, 613	2022, 519	2049, 532
Tilly	Sniff time	2037, 883	2009, 885	2023, 895	2045, 892
	Response time	2420, 933	2419, 924	2432, 943	2434, 971

## **Chapter 4**

### **Discussion**

The present study hypothesised that the dogs would be able to complete a cross-modal matching to sample task, using olfactory and visual stimuli at above chance accuracy, and that the addition of the correction procedure and physical touch screen border would both reduce position and shape bias, as predicted by Campbell-Smith (2024), and improve the dogs over accuracy of responding. It was also hypothesised that a simple visual discrimination task and the addition of an errorless learning procedure with the conditional discrimination task would also improve the dogs' overall response accuracy.

#### **Summary of Overall Findings**

The results of the conditional discrimination task were consistent across dogs, as all dogs were responding at above chance accuracy overall (see table four). Ralph had the highest range on the 95% binomial confidence intervals and demonstrated the most improvement in responding accuracy during the Conditional Discrimination (CD) task with the Errorless Learning Procedure (ELP) on his second attempt at 75% brightness, where his mean accuracy went from 56.9% to 67.9% for C1 and 57.4% to 66.5% for C2. This suggests that had we had more time for Ralph to complete more CD sessions without the ELP, his accuracy rate would likely have increased enough to meet the 80% mastery criteria. Indie, Tessa and Tilly also showed improvement for one or both odours on their second attempt at their failed level of the CD task with the ELP. As they all also had above chance accuracy overall on the CD task without the ELP, they may also have improved over time enough to meet the 80% mastery criteria. These results provide support for our first hypothesis, that dogs have the capacity to complete cross-modal MTS tasks with a

consistent rate of accuracy above chance. However, by the end of the data collection period, none of the four dogs had met the 80% mastery criteria for either odour and demonstrated high levels of variability in their responding (see tables four and five and figures 13, 14, 15 and 16) and the lack of time to complete further sessions and progress further.

There is some support for the second hypothesis, that the inclusion of the correction procedure and the physical screen border would reduce position/shape bias and improve overall accuracy of responding. The results showed that only one dog, Tessa, had a significant bias towards one shape (the cross) but none of the dogs had a significant bias towards any one position on the touch screen. These results could be attributed to the inclusion of the correction procedure and touch screen border, as Campbell-Smith (2024) did not use a correction procedure or touch screen border and observed both position and shape biases in her dogs, Indie for example was biased towards the circle and the top right position on the touch screen, which is why Campbell-Smith recommended they would be useful additions in future research. However, we cannot say that these additions had any significant effect on the overall accuracy of the dogs responding, as not all the dogs were responding above chance for both odours and none of the dogs were successful in meeting the 80% mastery criteria for either odour on the CD task.

While Indie was able to complete 139 sessions of the conditional discrimination task without the ELP, Ralph, Tessa and Tilly completed only 55, 42 and 30 sessions respectively. This was due to these dogs needing to first complete the training on how to interact with the apparatus (Indie was already trained from the previous year) and the addition of the simple visual discrimination task and the conditional discrimination task with the ELP. Ralph, Tessa and Tilly only started sessions for the conditional discrimination task without the ELP once they were no longer doing the conditional discrimination task with the ELP. This left only 2-4 weeks of lab

time to collect this data for Ralph, Tessa and Tilly. Tessa and Tilly also missed additional sessions throughout the year due to their owners travelling, so had even less time in the lab than Indie and Ralph.

As previously discussed, Ralph likely would have improved his accuracy rates to be above chance on the CD task without the ELP, judging by his performance on the CD task with the ELP, where his performance on both C1 and C2 improved considerably during his second attempt at 75% compared to his first attempt. Tessa also improved her accuracy on the CD task with the ELP on her second attempt at 75% for both odours, getting within 7% of meeting the 80% mastery criteria for C1, and Tilly improved her accuracy on her second attempt for C1, getting within 5% of achieving the 80% mastery criteria. These results also suggest that Tessa and Tilly may also have improved their accuracy on the CD task without the ELP if there had been time for them to complete more sessions.

All five dogs were able to meet the 80% mastery criteria for the simple visual discrimination task for both shapes. This task was included to investigate whether the dogs were having difficulty with the conditional discrimination task due to an inability to differentiate between the visual stimuli. The results, however, suggest that the dogs were capable of differentiating the two black and white shape images that were used during the conditional discrimination task, therefore it is unlikely that the dog's inability to meet the mastery criteria for conditional discrimination (both with and without the ELP) was due to the appearance of the visual stimuli provided.

Although the procedure was referred to as errorless learning, none of the four dogs who participated in the conditional discrimination task with the ELP were successful at meeting the 80% mastery criteria for all levels of the procedure (25%, 37%, 50%, 63% and 75%). After two attempts, Indie did not progress past 50% brightness, failing to meet mastery criteria

within 30 sessions on her second attempt (predetermined termination criteria). Ralph, Tessa and Tilly all reached 75% brightness, but did not meet the mastery criteria within 30 sessions after two attempts. One explanation for this could be that dogs have a higher brightness sensitivity to humans, due in part to the increased number of rods cells in their retinas, which are key in detecting changes in brightness levels and adjusting the amount of light the eye is exposed to (Miller & Murphy 1995; Yeh et al., 2017). Dogs also have larger pupils relative to the size of their eyes compared to humans, which also allows them to adjust their eyes to varying levels of brightness quicker. When the incorrect image was at a higher brightness and the brightness level is closer to the correct image at 100% brightness, the dog's eyes may have adjusted to the brightness of the incorrect image faster and been less able to differentiate the brightness level cues of the two images (Miller & Murphy 1995; Yeh et al., 2017).

Dogs' increased sensitivity to brightness could explain why three out of the four dogs were able to meet mastery criteria for the brightness levels below 75% but failed to do so once they reached 75% brightness. This also indicates that, during the ELP, the dogs were relying heavily on the brightness cue from the images as an indication of which image was correct, as opposed to using the odour they were smelling as the cue for which image was correct. Once the incorrect image was at the higher brightness level and was no longer providing a clue, due to the brightness levels being too similar, the dogs' responding became less accurate and consistent. This is related to the issue of prompt dependency, which is defined by Cividini-Motta and Ahearn (2013) as the learners' reliance on prompts or cues to perform a task or behaviour as opposed to acting independently. The difference in brightness was likely prompting the dogs to the correct response and, when this prompt was removed, the dogs were less accurate as their

behaviour was under the stimulus control of the brightness on the screen rather than the odours on the scent delivery.

We also hypothesised that the addition of the correction procedure and physical screen border would help to reduce biases in the dogs, as well as improve overall accuracy. Therefore, we examined the presentation and selection data for each screen quadrant and each shape, for each of the four dogs during the CD task without the ELP (see figures 16 and 17). While Indie, Tessa and Tilly chose the bottom right quadrant slightly more frequently than the other three quadrants, the results showed that none of the dogs had developed a bias towards any of the four screen quadrants (see figure 16).

By contrast, all four dogs in Campbell-Smith's (2024) previous study had a clear bias to either the left or right side of the screen and to a particular quadrant on their preferred side. Indie, for example, was biased towards the right side of the screen, choosing the top right quadrant most often in Campbell-Smith's study, however in the current study, Indie had the lowest percentage of responses to the top right quadrant (see figure 16) and was not biased towards any other quadrant. These results provide support for the second hypothesis, that the inclusion of a correction procedure and physical screen border would help to reduce quadrant biases in the dogs. Seeing as how every other aspect of the procedure was identical to what Campbell-Smith did, it is likely that the addition of the correction procedure and physical screen border were key in largely eliminating quadrant position bias in the dogs.

The other bias we examined was whether the dogs were biased towards one shape, selecting the cross or circle proportionally more often than it was presented (see figure 17). We found that only one of the four dogs, Tessa, had developed a shape bias towards the cross, while the other three dogs did not have a bias towards either shape. It is unclear as to why only Tessa

developed a shape bias where none of the other dogs did. While Campbell-Smith (2024) did not examine or comment on any shape bias in her research, it is likely that adding the correction procedure and physical screen border to the procedure for the current study did contribute to three out of four dogs not developing a shape bias.

We also analysed the sniff times and response times for each response type (cross correct, circle correct, cross incorrect and circle incorrect) for each dog on the CD task without the ELP (see table six) to see if the length of sniff (minimum sniff time was 1000 ms) and delay between the dog ending contact with odour and choosing an image had any impact on the dogs accuracy of responding. We found no significant difference in the sniff times or response times across response types for each individual dog, which suggests that neither sniff time nor response time had any significant effect on the dog's accuracy rates. In addition, the results also showed that Indie, who had the shortest average sniff times across every response type (all between 1150 and 1175 ms), was the least accurate overall in her responding on the CD task. However, the dog who was the most accurate overall on the CD task without the ELP, Ralph, had the second shortest average sniff times across all response types (all between 12300 and 1250 ms).

With regard to the response time, we were expecting that the longer the delay between contact with the odour and choosing a response, the more accurate the dogs would be. A faster response time could suggest the dog was not taking the time to look at both images before making a selection. The results showed that Indie had the shortest response times overall across all response types (all between 1700 and 1750 ms) and was the least accurate overall on the CD task without the ELP. By contrast, Tilly had the longest response times out of all the dogs across all response types (all between 2400 and 2450 ms) but had the second lowest accuracy rates overall on the CD task without the ELP.

## **Implications**

The initial goal of this research was to investigate dogs' ability to learn cross-modal associations by training them to match olfactory and visual stimuli. This would allow dogs to communicate to humans not only the presence or absence of an odour but also use visual stimuli to identify which specific odour they are smelling when it is present. The results from the current study were consistent with those of Campbell-Smith (2024), where all four dogs in the both studies had above chance accuracy rates overall and no dogs in the current study and only one dog in Campbell-Smith's study met the 80% mastery criteria.

Given that all dogs in both studies were able to work at above chance accuracy suggests that dogs are capable of learning cross-modal associations using olfactory and visual stimuli. However, given that none of the dogs in the current study and only one dog in Campbell-Smith's (2024) study met the mastery criteria for either odour, this suggests that the overall training and experimental procedures may need to be adjusted (for example, more gradual increasing of the ELP levels, such as 5% or 10% each time, and longer or continuous exposure to the odours in each trial) in order for the dogs to achieve the 80% mastery criteria for both odours. This could also result in less variability in the dogs responding, as all dogs in both the current study and Campbell-Smith's study exhibited high levels of variability in their responding.

Challenges regarding touch screen quadrant position biases faced by Campbell-Smith (2024) during her research (all dogs had a bias towards a side of the screen and/or a specific quadrant) prompted the inclusion of the correction procedure and the physical touch screen border in an attempt to reduce potential screen quadrant and shape biases. Given that these were the only procedural changes made from Campbell-Smith's (all other procedures were identical) and only one dog developed a shape bias, and no dogs developed a touch screen quadrant

position bias, we feel confident that the correction procedure and physical screen border were worthwhile additions to the overall procedure. We had hoped these additions would also help to increase the accuracy of the dogs responding on the CD task without the ELP, but results showed that the dogs in the current study were less accurate than those in Campbell-Smith's study. This again suggests that the fundamental experimental procedures should be adjusted in order to improve responding accuracy, however the correction procedure and physical screen border should remain within the procedure as they have been successful in reducing/eliminating shape and screen quadrant biases.

Further challenges faced in the current study prompted the addition of the simple visual discrimination (SVD) task and an errorless learning procedure (ELP) with the conditional discrimination (CD) task. The success of all five dogs (Gizzy successfully completed the SVD task prior to failing the last stage of training) in the SVD task suggested that the dogs were successfully differentiating the two images and allowed us to rule out the appearance of the visual stimuli as contributing to the dog's low accuracy and high variability in responding. These results are also consistent with those of Autier-Dérian et al. (2013) who found that dogs were able to visually discriminate images of different "dog" and "non-dog" species based on their physical characteristics.

Furthermore, although none of the dogs successfully completed every level of the CD task with the ELP, all four dogs did improve their accuracy on one or both odours on their second attempt at their previously unsuccessful level (see table three). This demonstrates that although the dogs were ultimately unsuccessful, given more time they would likely have continued to improve their accuracy and could have passed every level of the ELP and potentially also have met the mastery criteria (80% accuracy) for the CD task without the ELP.

We did not assess the ELP experimentally prior to including it in the experimental procedure, therefore we have no way of knowing with any degree of certainty whether it helped or hindered the dogs in the CD task. While we know that the existing experimental procedures need to be adjusted to improve the dog's accuracy with the CD task without the ELP, it is likely that the inclusion of an ELP in the training stages of the CD task could help to improve later accuracy with the CD task, as shown in Handley et al., (2023).

### **Limitations and Recommendations for Future Research**

There were several limitations with the current study. First was the time constraints, both for how long the researcher could conduct data collection in the lab and how many days the researcher had access to the lab, but also how many sessions could be conducted per week with each dog. The availability of the dogs was also a similar limitation, as dogs were only available in either the morning or afternoon for a few hours at a time and some of the dogs missed sessions due to their owners travelling. The time constraints also contributed to another limitation, which impacted only dogs new to the research (Ralph, Gizzy, Tessa and Tilly). The process of training the dogs to interact with the different apparatus took several weeks as there were 15 different stages of shaping for two separate apparatus, as well as chaining after all the shaping stages had been completed to ensure the dog interacted with all the apparatus in the correct order.

The addition of the simple visual discrimination task and the ELP during the data collection period also reduced the amount of time these dogs were able to participate in the CD task without the ELP, which meant they had a lot less CD without the ELP data than Indie to compare. Interestingly, while they did not reach the 80% mastery criteria, all four dogs improved their accuracy on one or both odours during their second attempt at the previously failed ELP level (50% for Indie and 75% for Ralph, Tessa and Tilly). Ralph in particular improved

significantly during his second attempt for both odours (see table three), which suggests that had there been more time to continue these ELP sessions and allow for further attempts at these higher brightness levels, the dogs may have eventually met the 80% mastery criteria for the higher levels of the ELP. Future researchers would benefit from having the dogs in the lab setting more often, ideally every day for at least four hours, in order to expedite training and maximise sessions. It could also be worthwhile for future researchers to do a between-subjects comparison of CD sessions with and without the ELP, such as that done by Terrance (1963) and later Handley et al.; (2023) in order to directly compare the dog's overall accuracy on the CD task with and without the inclusion of the ELP under the same experimental conditions.

The canine participants in this research were also recruited from the community, which meant they were domestic pets as opposed to dogs who were bred and trained specifically for scent detection research, as seen in the participant samples from Lazarowski et al. (2021) study. We did screen prospective dogs' levels of trainability in the initial meeting stage and during the early stages of training, and those who were deemed unsuitable or were not progressing in a timely manner or at all (as was ultimately the case with Gizzy), were withdrawn from the experiment.

Lastly, as previously stated by Campbell-Smith (2024) and earlier in the document, the overall experimental procedures may be the underlying cause of the dog's inability to meet the 80% mastery criteria for either odour. Some procedural recommendations made by Campbell-Smith, such as addition the physical border to the touch screen, did help to reduce biases in the dogs that were observed in her research, however, did not help to improve the dog's accuracy with the CD task without the ELP up to the 80% mastery criteria. We would recommend further procedural changes, such as increasing the minimum sniff time, using 3D visual stimuli instead

of 2D images, training the dogs to select a fixed position stimulus rather than a random position stimulus, having a more gradual increase of the ELP levels (starting with 5% brightness and increasing the brightness by 5% each time), and having the dogs successfully complete all levels of the ELP with the CD task prior to introducing the CD task without the ELP. Future research may also benefit more from an entirely different task designed to assess dogs' ability to make cross-modal associations using olfactory and visual stimuli.

## **Conclusion**

The present study demonstrates that dogs can discriminate odours and make indications using visual stimuli at an accuracy rate higher than chance (50%) using cross-modal association. We have also demonstrated that dogs can discriminate 2D visual images (based on the SVD task) and that the use of a correction procedure can help to reduce biases in the dogs. While this study and the previous study by Campbell-Smith has provided a procedural framework for cross-modal association research with dogs at above chance (50%) accuracy levels, further experimental procedural changes are still needed in order for dogs to achieve 80% mastery accuracy rates for the CD task without the inclusion of an ELP. With the right experimental procedures, it should be possible for dogs to achieve higher accuracy rates than those observed in the current study.

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## **Appendix A: Guidelines for Solution Preparation**

### **1. Purpose**

This standard operating procedure (SOP) provides guidelines and standardised procedures to be adopted during preparation of solutions during training and experimental phases of the experiment.

### **2. Solution Preparation for Experimental Sessions**

Solutions are prepared at the chemistry lab located in E block on the University of Waikato campus, under a fume hood. Covered shoes and personal protective equipment (goggles and a lab coat) are to be worn on the premises at all times. Disposable gloves are worn when handling chemicals and changed between handling new chemicals.

Chemicals are prepared individually. New volumetric flasks, 5mL beakers, 250mL beakers, and pipette tips are used in the preparation of each chemical solution. Paper towels are laid down for preparation in the fume hood. Gloves are disposed of and changed between the handling of each chemical. Cut the required number of parafilm prior to preparation of samples.

- 3.1 Wear a new pair of disposable gloves
- 3.2 Lay down paper towels prior to preparation of samples. Retrieve a clean set of glassware: a volumetric flask, a 5mL beaker, and a 250mL beaker. Place glassware on a paper towel. Fit the pipette with a clean tip.
- 3.3 Retrieve chemical concentrate from the storage cabinet and pour a small amount into the 5mL beaker.
- 3.4 Fill half the volumetric flask with deionised water (approximately 50mL)
- 3.5 Use the pipette to extract 25 microliters of chemical concentrate from the 5mL beaker and add it to the volumetric flask. Shake the flask well to ensure a mixture of solution. Using a 10mL plastic syringe, fill the volumetric flask to obtain 100mL of chemical solution.

- 3.6 Pour the shaken mixture into a Schott bottle. Repeat process to obtain 100mL of chemical solution and label the bottle with the name of the odour (linalool or cinnamaldehyde) using a permanent marker.
- 3.7 Seal Schott bottle with parafilm and cover the lid. Place Schott bottle into separate plastic bags to prevent any cross-contamination between chemical solutions.
- 3.8 Dispose of pipette tip and change gloves before preparation of the next chemical Solution.
- 3.9 Place all used volumetric flasks and beakers into a separate holding container. All used glassware will be placed into the acid bath for cleaning.

### **3. Disposal of Chemicals**

All remaining concentrates that were not used in the preparation of the chemical solutions are disposed of into chemical waste bottles in the chemistry lab. Linalool and Cinnamaldehyde should be disposed of into separate waste bottles.

### **4. Cleaning Products**

The preparation table is cleaned before any samples are prepared with an isopropanol solution (50% isopropanol, 50% water) and disposable paper towels.

Place all glassware used in the preparation of samples in the nitric acid bath for at least 24 hours.

The body of the pipette is cleaned with isopropanol solution, and disposable paper towels after preparation of each chemical.

If any spillage of solution occurs on the preparation table, this is cleaned with isopropanol solution and disposable paper towels. Gloves must be changed between cleaning the spillage and handling the next chemical solution.

## **Appendix B: Guidelines for Sample Preparation**

### **1. Purpose**

This standard operating procedure (SOP) provides guidelines and standardised procedures to be adopted during preparation of samples during training and experimental phases of the experiment.

### **2. Sample Preparation for Errorless learning and Experimental Sessions**

Preparation table is cleaned with an isopropanol (IPA) solution and disposable paper towels before preparation begins.

Cut the required amount of parafilm (two squares) before sample preparation

The pipette must always be kept upright with the tip facing down

- 2.1. Wear a new pair of disposable gloves
- 2.2. Place a paper towel on the preparation table
- 2.3. Place two clean vials on the paper towel, ensure they are clearly labelled “C1” and “C2” respectively using adhesive labels, remove disposable gloves and replace with a new pair
- 2.4. Uncap Schott bottle containing linalool (C1) and dispose of the parafilm
- 2.5. Retrieve a new pipette tip from the storage container and fit it onto the body of the pipette. Fill the vial labelled “C1” with 2 ml of linalool then dispose of the pipette tip
- 2.6. Seal Schott bottle of linalool with a new piece of parafilm and the lid
- 2.7. Replace disposable gloves with a clean pair, then uncap the Scott bottle containing cinnamaldehyde (C2) and dispose of the parafilm
- 2.8. Retrieve a new pipette tip from the storage container and fit it onto the body of the pipette. Fill the vial labelled “C2” with 2 ml of cinnamaldehyde
- 2.9. Seal Schott bottle of cinnamaldehyde with a new piece of parafilm and the lid
- 2.10. Place two vials containing samples on the scent deliver carousel in their predetermined positions
- 2.11. Using a new pair of gloves, clean the body of the pipette with IPA and disposable paper towels and place back into storage container

2.12. Using IPA and paper towels, spray and wipe down the counter and dispose of used paper towels

### **3. Disposal of Chemicals**

The chemicals that were used in experimental sessions are poured into separate Schott bottles and disposed of in the chemistry lab.

### **4. Cleaning products**

The preparation table is cleaned before any samples are prepared with an isopropanol (IPA) solution (50% isopropanol, 50% water) and disposable paper towels.

If any spillage of solution occurs on the preparation table, this is cleaned with IPA solution and disposable paper towels. Gloves must be changed between cleaning the spillage and handling the next chemical solution.

The body of the pipette is cleaned with IPA solution and disposable paper towels after preparation. New gloves are to be worn before cleaning the body of the pipette and are disposed of when complete.

## **Appendix C: Guidelines for Training Dogs for Scent Detection Work Using Automated Apparatus**

### **1. Purpose**

This standard operating procedure (SOP) provides guidelines and standardised procedures to be adopted during the initial training phase of the experiment.

### **2. Apparatus Setup**

Position the apparatus in the experimental room without other objects that may distract the dog. Only the front panel with the sample port hole should be accessible to the dog, and a ramp may be required for smaller dogs to access the sample port hole. Movable partitions should be used to block access to other sides of the apparatus. The room must have a door that closes/latches and should be equipped with cameras to monitor the dog at all locations in the room. The computer(s) used to control the apparatus and monitor the dogs should be positioned in the adjacent room.

### **3. Initial Training Phase**

This section outlines the basic training hierarchy for shaping by successive approximations. As a general criterion, each step must be completed three times independently by the dog before progressing onto the next stage of training. Keep sessions under 10 minutes.

#### **3.1 Introduction**

Once the dog has been habituated into the training environment, the researcher can proceed with the training sessions. During training, if the dog shows any sign of disinterest or fatigue, terminate the session immediately, preferably following the reinforcement of a correct response. Early training sessions should not exceed 10 minutes and dogs should be given a short break between each session.

### **3.2 Conditioned Reinforcer Establishment**

The researcher should enter the experimental room with the dog and stand to the side of the apparatus, preferably the side closest to the door. The researcher should be holding the wireless remote for the feeder and stand either with their hands behind their back or crossed at the front of their body, ensuring that the remote is out of view of the dog. The dog should then be allowed to explore the experimental room freely.

Standing near the apparatus and preferably close to the door, the researcher should avoid the dog's gaze to minimise unintentional cueing. This will then facilitate the fading of the researcher's presence in the experimental room. Gestural prompts may be used to facilitate training; however, these should be used only as needed and faded out before training is complete.

Food should be dispensed from the automatic feeder using the wireless remote until the dog immediately approaches the feeder upon hearing the sound made from the feeder when it is activated. Precaution should be taken not to trigger the feeder when the dog is sitting and staring at the feeder.

To move on to the next training stage, the dog should approach the automatic feeder and consume the food within 5 seconds of activation 3 times in a row.

### **3.3 Shaping of Nose to Port**

Once the sound of the automatic feeder has been established as a conditioned reinforcer, the wireless feeder remote should be used to train the dog to place their nose in the sample port of the apparatus. The method of differential reinforcement of successive approximations should be used to shape this behaviour.

For initial nose to port sessions, the apparatus should be turned off. Empty segments should be placed on the apparatus so that the dog can push the flap of the segment open. Be aware that the sound of the segment flap closing may initially startle the dog. Prompting, such as

gestural and/or verbal prompts, may be used, but prompting must be faded before proceeding to the next phase of training.

As soon as the dog is reliably placing their nose into the port far enough so that the segment flap is open, the dog should then be reinforced for leaving their nose inside the port for increasing lengths of time until they achieve the threshold for indication response time. **The indication response time should be set to 1000ms.** When the dog places their nose in the port, the apparatus will make a continuous beeping sound which will stop when the dog removes their nose from the port. Shaping should be continued until the dog begins to trigger the automatic feeder.

Once a run (15 trials) is complete at the 1000ms threshold, move on to the next training step. Ensure the behaviour of opening the flap is still occurring during this stage of training (ie. the dog is putting their nose far enough into the port to open the flap). If not, go back and do further shaping for opening the flap.

### **3.4 Shaping – Touch Screen**

With the apparatus turned off and not containing any segments, use the method of differential reinforcement of successive approximations to shape the use of the touch screen. Shaping for touch screen should also include touching the nose within each of the four quadrants, which are separated by a physical barrier to avoid the nose swiping from one quadrant into another.

Shaping with the touch screen should be done using a shape that will not be paired with a target odor later in the experiment. The training shape should be presented in one quadrant of the touch screen with the other three quadrants remaining blank. This can be done either by using a programme which presents images on the touch screen without first activating the scent apparatus, or by the researcher manually activating the scent apparatus. The dog should be reinforced with the automatic feeder for poking any part of the quadrant containing the training shape with their nose. Prompting (e.g., gestural and verbal) may be used during shaping, however, prompts must be faded and removed before proceeding to the next training step.

Once the dog has pressed the touch screen 10 times without the use of prompts and the touching the screen has been reinforced using manual activation of the feeder, move on to the next training step.

### **3.5 Simple Visual Discrimination**

Once the dog is reliably touching the image on the touch screen, they can begin the simple visual discrimination task, which has two stages. The dogs are introduced to two new images, a plus (+) and a triangle. During stage one, the plus is  $S^D$  (always correct) and the triangle is  $S^A$  (always incorrect). Once the dog has chosen the plus on their first try in at least 80% of trials for three consecutive sessions, they move on to stage two where the triangle is now  $S^D$  and the plus is  $S^A$ . Again, once the dog has chosen the triangle on their first try in at least 80% of trials for three consecutive sessions, they have passed stage two and completed the simple visual discrimination task. The dog has no interaction with the port or any odours during this task. The researcher should position themselves in front of the port to prevent the dog from interacting with it and to activate the touch screen as required by putting their hand in the port. The same programme should be used for the simple discrimination task as for the conditional discrimination task. The minimum sniff time should be adjusted to 100ms in the config file to ensure speedy activation of the screen for the dogs.

### **3.6 Chaining**

The next step requires the dog to complete the entire sequence of behaviours - putting their nose in the port and holding it in at least 1000ms (using a blank segment with no odor present), then moving towards the touch screen and indicating with their nose on the quadrant with the training shape, then (if correct) going to the automatic feeder to receive the edible reinforcement. Once this has been achieved, the researcher should remove themselves from the room once the dog is working successfully and independently. Once the dog is successfully completing the chain independently without the researcher in the room for two complete sessions (15 trials per session), displaying no signs of distress, they can begin the conditional discrimination task.

### 3.7 Discrimination Training

Load the apparatus with six segments, with two segments in places 1 and 2, and the other 4 placed to balance the lid of the apparatus. The two target chemicals should be arranged in segments 1 (C1) and 2 (C2), as per the specifications in the config file to ensure the correct odor is matched with the correct shape (C1 = cross, C2 = circle).

With the apparatus being switched on, bring the dog into the experimental room with the researcher standing beside the apparatus and closest to the door if possible. If the dog does not respond to the apparatus within 10 seconds, prompt the dog as required. When the dog sniffs the first sample, allow for 10 seconds before prompting to see if the touch screen is used without a prompt. Continue prompting where necessary but fade out prompts as soon as possible and be sure to prompt with a consistent cue.

Sample randomisation should be implemented from the beginning of the discrimination training and the same patterns should only be used up to a maximum of 3 sessions in a row before it is needed to be randomised again. After each randomisation, update the dogs config file. Continue until the correct response rate is above 80% without the use of prompts.

A correction procedure should also be implemented, whereby an identical trial is repeated in the event that the dog indicates on a non-target image or blank segment of the screen resulting in an incorrect match. The same segment should remain in the sniffing position on the apparatus and the images of the target shape and non-target shape should reappear in the same positions on the touch screen to ensure an identical trial situation. The same trial will be repeated until the dog indicates the correct shape to match the target scent and receives reinforcement from the feeder.

If the dog indicates on the incorrect quadrant 12 times within a single trial, the researcher should go into the room and prompt the dog to the correct choice (eg. using hand gestures or verbal instructions). Avoid eye contact as much as possible while in the room to minimise attention reinforcement. Once the dog indicates on the correct quadrant, the researcher should

leave the room and allow the dog to proceed independently. The researcher should also make a note of the odor and the quadrant position of the correct image on the touchscreen (eg. top left) from that trial for future reference as this information could later be useful to identify potential biases the dog may have towards a specific odor, shape or touchscreen quadrant.

### **3.8 Errorless Learning Procedure**

When the dog is first introduced to the conditional discrimination task with the two odours (Linalool and cinnamaldehyde) and two images (cross (X) and circle), an errorless learning approach with reduced brightness should be introduced. This is done by adjusting the brightness of the incorrect image in PaintShop Pro, so it will appear less bright than the correct image. There are successive levels of increasing brightness (25%, 37%, 50%, 63%, 75% and 87%) with the dogs starting with the incorrect image at 25% brightness, so it is 75% less bright than the correct image. Once the dog meets the mastery criteria (correct on first try for at least 80% of both cross correct and circle correct trials across three consecutive sessions), the brightness of the incorrect shape is then increased to 37%. Each time the dog meets mastery criteria for the brightness level they are at, the brightness of the incorrect image should be increased to the next highest level until both images are at 100% brightness. Both the cross and the circle images should have copies made at each level of opacity, as depending on the randomised order of which shape is correct, the incorrect image needs to appear at the correct level of opacity. The “correct stimulus” file for each dog should have the incorrect image adjusted to match the order of the correct odour/image pairings each time the order is randomised (every 4 sessions).

## **4. Appendix: Troubleshooting Tips**

If the dog is performing poorly in training:

- Make sure that the dog is healthy and deal with any health-related issues.
- Confirm that there have been no significant changes in the dog’s home routine (e.g., moving house).

- Confirm that the food being used is an effective reinforcer by evaluating approach, interest, and consumption. If the food being used is not an effective reinforcer, try a different type of food.
- Return to the earlier stages of training as required (e.g., if the dog is not reliably using the touch screen during discrimination training, conduct another touch screen shaping session).
- If the dog continues to perform poorly, consult with your supervisor. The dog may need to cease participation in the study.

## **5. Appendix: Guide for**

### **Shaping Procedure**

#### **5.1 Shaping for Sample Port Entry**

- 5.1.1. For initial sessions, the apparatus should be turned off. Empty segments are to be placed on the apparatus so that the dog can push the flap of the segment open. The sound of the flap closing makes a loud, sharp noise which may startle the dog to begin with.
- 5.1.2. Reinforce moving further away from the feeder, until the dog is reliably approaching the side of the room near the apparatus.
- 5.1.3. Reinforce attending to the apparatus (putting their nose near/on any part of the front panel of the apparatus).
- 5.1.4. Reinforce nose near port.
- 5.1.5. Reinforce nose in port.
- 5.1.6. Reinforce nose touching and opening the flap (this is indicated by the sound the flap makes when the dog's nose makes contact).
- 5.1.7. Reinforce pushing the flap further inwards
- 5.1.8. Reinforce pushing flap inwards and holding nose in port for 500ms
- 5.1.9. Turn the apparatus on and it will now make a continuous beeping noise when the port beam is broken.

5.1.10. Continue to reinforce beam breaks and push the flap inwards, until the dog is fully opening the flap and breaking the beam for 1000ms.

## **5.2 Shaping of Touch Screen use**

5.2.1. Turn apparatus off and do not load the segments with samples.

5.2.2. Reinforce any movement towards the touch screen.

5.2.3. Reinforce any movement of the nose (as appropriate) towards the screen.

5.2.4. Reinforce any nose (as appropriate) contact with the screen.

5.2.5. Reinforce the dog making contact with their nose on the touchscreen quadrant which contains the training shape - the dog should be exposed to the training shape in each of the four quadrants randomly to minimise position bias

## **5.3 Visual Discrimination**

5.3.1 Reinforce choosing the plus ( $S^D$ ) image on the touch screen. If the dog chooses the triangle, do not reinforce and repeat the identical trial until the dog chooses the plus.

5.3.2 Once mastery criteria met for the plus, reinforce choosing the triangle ( $S^D$ ). If the dog chooses the plus, do not reinforce and repeat the identical trial until the dog chooses the triangle.

## **5.4 Behaviour chain**

5.4.1 Reinforce the dog breaking beam for 1000ms, activating touch screen, then making nose contact with the quadrant containing the shaping image

5.4.2 Experimenter stays out of the room, dog completes previous step independently