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**Exploring Cross-Modal Association in Canine (*Canis familiaris*) Scent Detection: A
Framework for Training Dogs to Identify Multiple Odours**

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Abstract

Dog's olfaction abilities and trainability have made them valuable companions in scent detection tasks for centuries. While research has focused on dogs detecting single odours, there is a gap in understanding if they can emit different responses to different odours. Based on the principles of stimulus control and existing evidence of dogs' ability to learn to perform similar tasks, it was hypothesised that dogs, using cross-modal association through olfaction and vision modalities, can match odours to corresponding shapes. Using an automated scent delivery apparatus, four dogs were trained using operant conditioning procedures to discriminate between two odours and select a corresponding shape. One dog met the mastery criteria and progressed to three odours. It was found that dogs were able to discriminate between odours at greater accuracy than chance, confirming our hypothesis. Yet, all dogs did display a bias towards one of the four touchscreen quadrants. The findings were similar to those observed in other studies involving different animal species, but the accuracy rates observed in this study were lower than those reported in other similar studies. These findings have implications for tasks the detection of multiple scents and further the understanding of dogs' abilities to perform cross-modal discrimination tasks. This study established a methodological framework for cross-modal scent discrimination tasks but there are several improvements to the methods that might enhance dogs' performance in future research.

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Chapter 1

Introduction

Introduction

The exceptional olfactory capabilities of dogs (*Canis familiaris*) have garnered widespread recognition, establishing dogs as valuable partners to humans in a myriad of scent detection tasks for many centuries (Browne et al., 2006; Gazit & Terkel., 2003; Johnen et al., 2013). Dogs are frequently employed to aid humans in tasks ranging from detecting explosives and narcotics to more complex odours, like cancers and endangered species, such as the kiwi (explosives; Browne et al., 2006; narcotics; Lee Rice & Velasco, 2023; cancers; Kudlak et al., 2023; endangered species; Robertson & Fraser, 2009).

Extensive research has established that dogs have superior olfactory capabilities to humans (see Kokocińska-Kusiak et al., 2021), as the unique anatomical structure of the nose is pivotal to a dog's olfactory functioning. Dogs possess two types of inhalation; sniffing and breathing. When breathing, air flows throughout the nasal cavity, with only 12 – 15 % of inhaled air reaching the sensory part of the nose, the olfactory epithelium. Whereas when sniffing, a unique nasal airflow pattern is established, optimising the delivery of odorants to the epithelium (Craven et al., 2007; Walker et al. 2003, 2006). This optimisation is achieved by having a dedicated olfactory recess in the epithelium, located at the back of the nasal cavity and separate from the main respiratory passage. Consequently, dogs experience a unidirectional airflow during inhalation, with air being trapped near the olfactory receptor cells (ORCs), allowing for longer exposure times to odours and periods of stagnant air during exhalation (Craven et al., 2007, 2010; Stejskal, 2023; Walker et al., 2003, 2006).

In a dog's epithelium, there are two kinds of receptor cells: the epithelium cells, which are responsible for filtering the incoming air, and the ORCs, which are responsible for the interpretation of odours (Jenkins et al., 2018; Kokocińska-Kusiak, 2021; Stejskal, 2023).

Within the epithelium, it is estimated that dogs have between 200 to 300 ORCs, while humans only have around five million (Lindsay, 2000). These ORCs regenerate every 60 to 90 days and it is this regeneration that is believed to enhance dogs' olfactory abilities over time by maintaining a high level of sensitivity to odours. This allows the new cells to remain functional and responsive to new odours by preventing desensitisation (Bamford, 2015; Gerritsen & Hank, 2015; Stejskal, 2023). Dogs exhibit significant differences in receptor cell quantities and regeneration compared to humans, which suggests that dogs have a much greater capacity for detecting and distinguishing between odours. As dogs' noses are extremely sensitive and are able to detect odour concentrations as low as one to two parts per trillion, their olfactory capabilities surpass human capabilities by approximately 10,000 to 100,000 times for certain odours (Craven et al., 2010; Walker et al., 2003, 2006).

Building on their olfactory acumen, dogs' remarkable trainability renders them ideal partners for humans in scent detection tasks. Dogs are readily trained using operant conditioning, which involves presenting a reinforcer, such as a preferred food when a desired behaviour is emitted (Skinner, 1953). This approach can be used to train dogs to assist their handlers in locating scent-based targets. By reinforcing the emission of a response when the desired odour is present, dogs are more likely to indicate the presence of the desired odour by emitting the response when they encounter that odour again in the future. The emission of a response, when a desired odour is detected, can then be used by the handler to identify when that odour is present.

The current body of literature investigating dogs' scent detection abilities highlights a notable gap in the research regarding their ability to emit different behaviours in the presence of different odours. While there is substantial research confirming dogs' abilities to detect and respond to a single odour (see Beebe et al., 2016; Juge et al., 2022; Oldenburg et al., 2016), the investigation of whether dogs can emit different behaviours in the presence of

different odours remains relatively unexplored. Filling this research gap can offer valuable insights into the extent to which dogs can be used to detect multiple odours, contributing to advancements in understanding animal learning and practical applications. For example, when detecting contraband, dogs could provide more specific indications to their handlers, emitting one behaviour when detecting narcotics and emitting a different behaviour when detecting explosives, ensuring the contraband is handled safely and correctly.

Multiple Scents, Multiple Targets

The three-term contingency is a fundamental concept in operant learning theory. In essence, the three-term contingency involves three components: (1) an antecedent stimulus or discriminative stimulus (S^D), (2) a behaviour, and (3) a subsequent consequence, either a reinforcer or punisher (Mazur, 2015). Behaviours that are followed by reinforcers are more likely to recur in the future, while those followed by punishers are less likely to recur in the future (Skinner, 1953). After repeated exposure, the association of the discriminative stimulus (S^D) with the reinforced response increases the likelihood of the behaviour occurring in the presence of the S^D (Iversen, 1992). Conversely, an antecedent stimulus that predicts the unavailability of reinforcement for a response, is known as the S-delta (S^Δ). In the presence of the S^Δ , the probability of the response occurring decreases. For example, Lazarowski et al. (2021) demonstrated the applicability of the three-term contingency in accordance with scent detection: the dog was presented with an odour (S^D), sitting (the behaviour) was reinforced (the consequence) in the presence of the S^D but not in its absence or in the presence of the S^Δ . After sufficient exposure to these conditions, correct responses and correct rejections were increased to 99% and incorrect responses decreased to 1%.

The three-term contingency proposes that different behaviours can be evoked in the presence of different stimuli, a phenomenon known as stimulus control. In essence, stimulus control represents the degree of influence a specific stimulus or environmental event exerts

over an organism's behaviour, and how it is established and maintained through the reinforcement contingencies that follow the behaviour (Blackman, 1974; Iversen, 1992). When consistently exposed to the reinforcement contingencies for specific behaviours in the presence of the S^D , these stimuli gain control over the exerted behaviour. As a result, the occurrence of the behaviour becomes predictable in the presence of the S^D associated with reinforcement for that behaviour. For example, following training in which sitting has previously been reinforced in the presence of a narcotic (S^{D1}), and lying down has been reinforced in the presence of an explosive (S^{D2}), these different responses should then be evoked when in the presence of the relevant odour. Considering that the number of different responses dogs can readily emit to indicate if the presence of different odours is limited, it would be useful to train dogs to interact with other stimuli to indicate which odour out of a larger range of odours they are detecting.

The complexity of stimulus control often extends beyond the basic three-term contingency, as demonstrated by conditional discrimination. Conditional discrimination is a behavioural phenomenon that refers to when a response is evoked in the presence of a contextual stimulus and an S^D , signalling the availability of the reinforcer (Catania, 1998). In this context, the behaviour is under the stimulus control of the S^D ; however, the response is only evoked when the S^D is presented in conjunction with the contextual stimulus, demonstrating that the behaviour is under the operant control of both stimuli (Axe, 2008; Catania, 1998). Byosiere et al. (2017) demonstrated a successful conditional discrimination task with dogs in the visual domain. Using a two-choice visual discrimination paradigm, Byosiere et al. assessed dogs' capacity for learning relational concepts, by training the dogs to identify the larger of two circles, with reinforcement being contingent on selecting the larger circle. In this task, the smaller circle was the contextual stimulus and the larger circle

was the S^D . It was found that after 800 trials, the dogs could accurately discriminate between the two circles with 100% accuracy.

The principles of conditional discrimination then suggest that when in the presence of a contextual stimulus and two S^D s, the contextual stimulus determines which S^D evokes the relevant response, implying that a previously reinforced response should be evoked in the presence of one S^D , while a different, previously reinforced response should be evoked in the presence of the other S^D (Axe, 2008; Catania, 1998). Lazarowski et al. (2021) conducted a successful conditional discrimination task with dogs. In this task, dogs learnt to discriminate between sample odours (contextual stimulus). that matched the just-presented odour, and a different odour, with the presence of both odours serving as the S^D . Dogs were then reinforced for sitting in front of the sample odour and ignoring the different odour. While this study suggests that evoking different behaviours in the presence of different S^D s and contextual stimuli is plausible, research exploring this phenomenon across sensory modalities remains limited. Despite some challenges in feasibility, investigating how dogs engage with stimuli across multiple sensory modalities could reveal whether this type of control can be established, ensuring that the response occurs reliably in the presence of both the contextual stimulus and the S^D .

Cross-modal association

Environmental objects typically possess multiple sensory characteristics, which can be perceived across various sensory modalities (Marks, 2004; Reichart et al., 2016). To achieve a cohesive and unified perception, organisms require the capacity to integrate information from multiple sensory modalities, a phenomenon known as cross-modal association (CMA) (Bruck et al., 2022; Speed et al., 2021). Cross-modal association refers to a learning process where a response becomes associated across sensory modalities, allowing for the evocation of the response regardless of the modality in which the stimulus is

presented, such as vision, olfaction, or other senses (Youngentob et al., 1990). CMA facilitates the transfer of learned responses across different sensory modalities, enabling the organism to respond appropriately to stimuli encountered through various senses. For instance, a dog trained to fetch a ball might not respond to the sight of the ball alone, for example when presented on the TV, but when both the visual stimulus (ball) and an olfactory cue (scent of the ball) are presented simultaneously, the dog fetches the ball, demonstrating the necessity of both sensory stimuli to evoke the response. The merging of multi-sensory information has been found to aid in perceptual decision-making (Bizley et al., 2016; Bolam et al., 2022), leading to faster response times (Kayser & Kayser, 2018; Silva & Bellini-Lite, 2020), enhanced decision accuracy (Franzen et al., 2020; Kayser & Kayser, 2018), and improved detection of objects (Adam & Noppeney, 2014).

Cross-modal association can also be framed as a conditional discrimination task in which the response is evoked based on the conditional relationships between sensory stimuli from different sensory modalities, needing two different sensory stimuli present to evoke a response. Behavioural experiments have explored this phenomenon, observing how animals trained in conditional discrimination tasks exhibit behaviours when presented with stimuli from different sensory modalities (see Kawachi, 1968; Srinivasan et al., 1998; Youngentob et al., 1990).

Relevant Literature

There are currently limited publications available on how cross-modal association may assist dogs in conveying information about detected stimuli during scent detection tasks. However, previous research on other animal species has demonstrated that CMA can enable animals with the ability to indicate changes in sensory stimuli, as observed in research involving rats and honeybees.

When attempting to gain information about what animals are perceiving, it is essential to provide the animals with an alternative response method, replacing human verbal responses and enabling an interaction between the animal and the experimenter. Youngentob et al. (1990) developed a procedure for this purpose. To do so, a go/no-go paradigm was employed that used six contextual stimuli: five odorants and one blank odorant. The rats were then placed into a chamber equipped with five attached response tunnels, with each tunnel having unique visual and tactile stimuli. An odour was then presented into the chamber and the rat could respond by either entering into the tunnel associated with reinforcement for that specific odour or remaining in the main chamber, signalling a blank indication. Reinforcement was then contingent on entering the correct response tunnel or remaining in the main chamber. Youngentob et al. found that the cross-modal paradigm is a successful technique for providing rats with an alternative response method. This was evidenced by the rats achieving above chance accuracy, at a 95% correct response rate, with the rats accurately identifying changes in the quality of the five odorants

A follow-up study was then conducted, where Youngentob et al. (1991) repeated this procedure, however, the initial five odorants were increased to 10, with one of these odorants being a blank. Similar results were found, with the rats achieving above chance accuracy, at a 92.5% correct response rate. Again, the rats successfully indicated changes in odorant quality. Youngentob et al.'s approach in both studies demonstrates how CMA is a conditional discrimination procedure, in which reinforcement of the response of entering the correct tunnel was contingent upon the presence of both the odour and the specific tactile and visual stimuli of the response tunnel. In these experiments, the odorant acted as the contextual stimulus and the specific tunnel-related stimuli acted as the S^D .

A subsequent study examining CMA involved an experiment investigating honeybee's ability to cross-modal associate colours with odours (Srinivasan et al., 1998).

Similar to the methodology used by Youngentob et al. (1990, 1991), Srinivasan et al. utilised a two-chamber arrangement. The initial chamber presented the odour, while the second chamber required the bees to select between two exits. Two fruit odorants were used, one odour being associated with reinforcement for approaching the blue exit, and the other odour being associated with reinforcement for approaching the yellow exit. The honeybees then received reinforcement contingent on approaching the correct exit corresponding to the odour-colour association. The results indicated that after a single day of training, the honeybees exhibited above chance accuracy in matching the odours with colours.

Considerations and Approaches

Building on the work conducted by Youngentob et al. (1990, 1991), the present study aims to adapt the experimental paradigm to suit canine subjects and canine scent detection. Specifically, it aims to investigate the capacity of domesticated pet dogs to convey information regarding detected odours through a cross-modal framework. Furthermore, this study aims to examine whether dogs can discriminate between multiple odours and produce distinct responses for each detected odour. To facilitate this, several adaptations have been made to Youngentob et al. experiment to make it suitable for dogs.

Firstly, a computer-controlled scent delivery apparatus that was operated by the dogs was used, which allowed the experiment to be conducted without the experimenter present, mirroring Youngentob et al. (1990; 1991) approach. This approach has been implemented as it has successfully been used in previous experiments (Edwards, 2019; Edwards et al., 2022). Additionally, this approach reduces the potential unintentional cueing by the experimenter that might otherwise influence the responses of the dogs. Furthermore, the response tunnels from the original designs were replaced by a touchscreen interface displaying distinctive visual stimuli. Instead of entering a response tunnel or exit to make their response selection, dogs were required to respond using the touchscreen which presented two black and white

shapes: a circle and a cross. These shapes were chosen based on previous research demonstrating dogs' ability to easily discriminate between them (Byosiere et al., 2018).

In scent detection literature, dogs are often provided with a rejection response, where all odours except the target odour are to be rejected, such as the blank response in Youngentob et al.'s (1990) approach (see DeChant et al., 2021; Lazarowski et al., 2020). In the present study, the intention was to train the dogs with a rejection response associated with the cross on the touchscreen. Starting with one target odour and one non-target odour, and as dogs met the mastery criteria of above 80% correct responses for each odour across three consecutive sessions, another target odour associated with a new shape, and another target odour associated with the cross would then be introduced. However, given the slow progress of the dogs, all dogs but one were only exposed to the two odour-shape pairings and one dog was exposed to one odour-shape pair and two non-target odours associated with the non-target visual stimulus.

Drawing on the CMA theoretical framework and Youngentob et al.'s (1990) research, adapting this approach appropriately for dogs should lead to accurate responding in the presence of cross-modal stimuli. Therefore, it was hypothesised that through CMA, involving both olfaction and vision sensory modalities, dogs would be able to conditionally discriminate between multiple odours and make response selections with greater accuracy than chance about which odour has been detected.

Chapter 2

Methodology

Subjects

All dogs used in the experiment were recruited through the use of social media posts, word of mouth, or had previously been used in university scent detection experiments and their owners had expressed interest in their dog being used in future experiments. At the preliminary stage, dogs were introduced to the scent detection facility for an initial assessment aimed at determining their eligibility to partake in the experimental study. During this assessment, dogs were evaluated for food motivation and any signs of distress in the laboratory environment in the absence of their owners. If the dog either exhibited distress, a lack of food motivation, or both, they were not eligible to participate in the study.

To increase the reinforcing effectiveness of food during sessions owners were requested to not feed their dog two hours before being brought into the scent detection facility. All dogs underwent training with an automated feeder that released kibble upon manual activation using a wireless remote control. To progress to the next training stage the dog was required to reliably approach and eat the dispensed kibble within three seconds of the feeder being activated.

Sessions were conducted four days a week, either in the morning or afternoon. Most dogs participated in two sessions a week across two separate days. However, due to the owners' availability to pick up their dogs, some dogs completed full-day sessions. All dogs were dropped off and picked up by their owners at previously arranged times.

Seven dogs were recruited to participate in this experiment. Four dogs had previously been used in scent detection experiments, with three dogs being familiar with the scent detection apparatus and one was not. An additional three dogs were evaluated and one dog

did not proceed past the initial evaluation due to exhibiting distress in the experimental room. Furthermore, two dogs were withdrawn due to health concerns and a lack of motivation. Four dogs remained in the experiment.

Table 1

Subject information

Name	Breed	Age	Weight	Sex	De-sexed
Indie* ⁺	Weimaraner	3yrs	32.8kgs	F	Yes
Sabi* ⁺	Labrador	11yrs	31.3kgs	F	Yes
Cobie*	Labrador X	12yrs	26.8kgs	F	Yes
Harlee* ⁺	Labrador	10yrs	31.2kgs	F	Yes
Bear	Maremma Sheepdog	1yrs	35kgs	M	No
Penny ⁺	German Shepherd	1yrs	28kgs	F	No
Amber ⁺	Labrador	2yrs	28.2kgs	F	Yes

Note. * subjects who had been used in previous scent detection work

Note. ⁺ subjects who participated in the experiment past the initial training stage

In the facility, dogs were kept in separate crates where they had regular access to a mat, a blanket, and water. Dogs were taken on a walk outside every two hours by the experimenter. All experimental procedures, including handling and care procedures, were approved by the University of Waikato Animal Ethics Committee (Protocol #1160).

Experimental Equipment

The equipment used for this experiment consisted of a touchscreen, a scent delivery apparatus, an automated feeder in the experimental room, and two computers; one used for filming the sessions and one used for running the apparatus in an adjacent room.

The touchscreen device (model PQ Labs G4 27") worked using IR touch technology, where disruptions to the light pattern were detected, noting the exact location of such interruption as a touch point (Yang, 2023). The touchscreen device was attached to a Dell™ computer monitor (model P2714Hc, with 1920 x 1080 resolution). The touchscreen was attached to the right of the scent detection apparatus, 1.19 m away from the apparatus. The touchscreen sat 28 cm above the ground and was situated at an angle of 120°. The screen was divided into four equal portions with each portion measuring 150 x 250 mm, with a 50 mm black border to separate the quadrants, as shown in Figure 1. Each touchscreen quadrant measured 30 x 17 cm. When activated, the touch screen displayed two black shapes, a circle and a cross, on a white background, with the other two quadrants of the screen remaining black. Refer to Appendix A and B for images of the shapes used. The positions of the shapes were randomised for each trial. Responses could only be made to the portions of the screen with the shapes displayed.

Figure 1

Arrangement of the screen quadrants

1	2
3	4

The scent delivery apparatus consisted of a 1-m³ frame that housed a carousel and had an acrylic panel attached to the front of the frame, where the dogs accessed the odour sample on the carousel through a nose port in the middle of the acrylic panel. The carousel had a diameter of 76 mm and held 17 removable segments (280 mm x 135 mm x 8 mm, volume 3.57 L). Each segment featured a square opening measuring 100 mm by 100 mm, positioned at the front top, covered by a stainless steel flap that opened inwards. The flap was equipped with a weighted L-bracket, enabling it to open to an angle of 28°. This design ensured that the dogs could not access the opening to a degree where they would come into contact with the sample and held the flap closed when the segment was not being accessed by the dog. There was a square, metal tube positioned at the bottom rear on the inside of each segment to hold the odour sample vial in place and ensure it did not spill. A round metal lid, the same diameter as the carousel, was then placed on top of the segments to prevent cross-contamination.

Custom software was used to operate the apparatus, controlled by a computer located in the adjacent room to the experimental room. The software controlled the scent delivery apparatus, the touch screen, and the feeder.

The dogs accessed the odour sample by placing their nose through a 90 mm port located in the middle of the front acrylic panel, pressing the flap of the segment positioned behind the port open. When the dog's nose was in the port, an infrared beam was broken, producing a constant buzzing noise for audio feedback. Once the dog had placed their nose in the port for 1s, the buzzing ceased and a "beep" was made and the shapes appeared on the touchscreen, indicating that it was ready for a response. Once a response was made to the touchscreen, the touchscreen went black and the carousel rotated to present the next sample at the port. When the scent delivery apparatus was ready for a response, two consecutive "beeps" were made to indicate that the next trial could begin. If the dog placed their nose in

the port as the apparatus was turning, it ceased moving to indicate that the apparatus was not ready for the next trial and to prevent injury. The duration of the inter-trial interval was approximately 2s, however, the inter-trial interval was increased if the dog placed their nose into the port when the carousel turned, interrupting the rotation.

Correct responses were operationally defined as any instance where the touchscreen was activated at the coordinates of the quadrant that contained the shape that corresponded with the just-presented odour. Linalool (C1) and amyl acetate (C3) were both non-target odours and were associated with the cross, and cinnamaldehyde (C2) was a target odour and was associated with the circle. Incorrect responses were operationally defined as instances where any body part activated the coordinates of a shape on the touchscreen which was not associated with the just-presented odour. To record a response, the dog was required to interact with a specific quadrant on the screen containing a shape. Any responses directed at blank quadrants were not considered valid, requiring the dog to make contact with one of the shape-containing quadrants before advancing to the next step of the trial.

For each correct response, an automatic feeder was triggered, accompanied by a distinct “*ding*” sound to provide audio feedback for the dog. Concurrently, food was dispensed followed by the carousel turning. Conversely, for incorrect responses, two successive low-pitched “*beeps*” occurred serving as audio feedback and no food was dispensed. The carousel then turned for the next trial.

Two automatic feeders were used in this experiment, one for dry food and one for wet food. The dry food feeder was a Treat and Train Remote Reward Dog Trainer™, which administered Pedigree® beef-flavoured kibble. The second feeder was a custom-built feeder designed for wet (or any) food. The wet food feeder housed 16 removable stainless steel ramekins, which sat on a round, acrylic panel that had cut-outs for each ramekin to sit in, ensuring they did not move out of place as the feeder rotated. A wooden lid sat on top of the

feeder, with an opening lined with an acrylic panel located at the front of the feeder, allowing the dogs to access one ramekin at a time. When activated, the feeder turned clockwise in one position. Possyum, a meat paste, was used in the wet food feeder. The different feeders were employed for different dogs based on an assessment of which type of food functioned as an effective reinforcer.

Chemicals

A total of three chemicals were used in the experiment (linalool, cinnamaldehyde and amyl acetate). The chemicals used were selected according to meeting three criteria: 1) the chemical is known to produce a distinct odour, 2) the chemical is not aversive or harmful to humans or dogs at the concentration used, and 3) the chemical had been previously used in prior canine scent detection research.

All concentrated chemicals were stored in a chemistry laboratory in a secured, flammable storage cabinet. All chemical solutions were stored at the scent detection facility. After use, all chemicals were disposed of safely, following the chemistry laboratory's health and safety guidelines.

Solution Preparation

In the first stage, two chemicals were used, one non-target odour (linalool) and one target odour (cinnamaldehyde). At the second stage, one dog increased to three chemicals; two non-target odours (linalool and amyl acetate) and one target odour (cinnamaldehyde).

All solutions for this experiment were prepared in the same manner. Chemical solutions were prepared by pouring 50 ml of deionised water into a 250 ml Schott bottle. 50 μ L of the chemical was then added to the Schott bottle and mixed well. Deionised water was then poured into the Schott bottle until 100 ml of the chemical solution was obtained, making the water-to-chemical concentrate dilution ratio 2000:1. The ratio was decided upon as all chemicals were able to be easily distinguished between by humans, yet not so powerful that

the dogs would likely be overwhelmed by the intensity. The bottles were then sealed and placed into individual resealable bags and were stored for up to two weeks at room temperature. Solutions were disposed of and replaced every two weeks. Refer to Appendix C for the standard operating procedures for solution preparation.

Sample Preparation

All samples used in the experiment were prepared in the same manner. Vials were labelled using self-adhesive labels that were placed in the middle and horizontally on the vials. Vials containing cinnamaldehyde were marked using a pen with a C, linalool with an L and amyl acetate with an A. Samples were prepared by extracting 2 ml of solution and transferring it to the labelled vials using an auto pipette. The auto pipette tips were changed in between the preparation of each odour sample and the auto pipette was wiped with isopropyl alcohol. Each vial was then placed into the predetermined segment of the apparatus. One sample of each odour was used on each day, and the scent delivery apparatus turned to the relevant segment to present the programmed sample for each trial. Refer to Appendix D for the standard operating procedures for sample preparation.

Initial Procedures

In the initial training stages, the experimenter utilised operant conditioning procedures, employing both shaping by successive approximations and behavioural chaining. Shaping by successive approximations involves the reinforcement of behaviours that are increasingly topographically similar to the target behaviour, and placing behaviours that are dissimilar to the target behaviour under extinction (Ploog, 2012). To begin, the feeder was established as a conditioned reinforcer by activating the feeder and dispensing food. Shaping then began when the dogs were reliably approaching the feeder.

The next stage involved training the dog to use the scent delivery apparatus reliably. This involved the dogs placing their nose inside the nose port, ensuring that the flap on the

segment was pushed inwards, giving the dogs access to the odour inside. Sabi and Harlee, having prior experience with the apparatus, required minimal, if any, shaping. For the other dogs, shaping begun by reinforcing the behaviour of turning towards the nose port. Once this behaviour occurred reliably, the reinforcement shifted to approaching the nose port. Subsequently, reinforcement was contingent upon the dog placing its nose in the port. This phase often involved verbal or gestural prompts to prompt the dog to complete this stage. For dogs unfamiliar with the apparatus, this shaping phase spanned a minimum of two sessions. This shaping phase concluded when the dog consistently and independently placed its nose inside the port, pushing the flap back, without any prompting from the experimenter.

Initial touch screen shaping involved reinforcing any form of interaction between the dog and the touchscreen. Similarly, prompts were used based on individual dog requirements. Once this interaction was occurring reliably either a circle or star was displayed on the screen, and then only touching the quadrant with the shape was reinforced. Most commonly, this interaction was the dog pressing their nose to the screen, however, some dogs used their paws. Originally, the circle, which was associated with C2 during the experiment, was used during this shaping phase. However, the experimenter observed during the experimental phase that the dogs presented a bias towards the circle. The dogs that were trained using the circle and demonstrated a bias towards selecting the circle were Indie and Sabi. After this observation, instead of a circle, a star was used to minimise future bias towards selecting the circle. Amber, and Penny, who joined the study later, were trained only using the star. Once the dog was independently and reliably using the touchscreen, the next shaping stage began.

To complete the behavioural chain, reinforcement was contingent on the dogs autonomously executing all steps without prompting and in the absence of the experimenter in the experimental room. This behaviour involved the dog placing its nose inside the scent delivery apparatus to push the flap back, then approaching the touchscreen to select the star

shape, and finally, approaching the feeder for reinforcement. The behavioural chain needed to be completed five consecutive times for the dog to progress to the experimental phase.

However, for Amber, completing this behavioural chain without the presence of the experimenter was omitted and the chain needed to be completed without prompting from the experimenter. Ensuring dogs worked autonomously was crucial to avoid unintentional cues from the experimenter, preventing the dogs from responding based on unintentional information. Meeting this criterion indicated the dog's readiness to advance to the experimental phase, avoiding the possibility of the dog responding to unintentional cues rather than the experimentally intended stimuli. Refer to Appendix E for the standard operating procedures for training dogs for scent detection work using an automated apparatus. A video of Indie working with two odours and two corresponding shapes can be found at the following link:

<https://drive.google.com/file/d/1C3BZ8HNA7OQqOX1fBE5XnPvtLDOtoJ7w/view?usp=sharing>

Experimental Procedures

In the experimental training stages, discrimination training was utilised to teach the dogs how to differentiate between two or more odours. This process involved using differential reinforcement where either reinforcement was administered or withheld to increase or decrease the likelihood of that behaviour occurring again in the presence of the relevant stimuli (Skinner, 1953). This was achieved by reinforcing the selection of one shape in the presence of one specific odour, and not reinforcing the selection of another shape. To begin, selecting the cross when in the presence of linalool (C1) was reinforced and, in conjunction, selecting the circle when in the presence of cinnamaldehyde (C2) was reinforced. Therefore, in the presence of linalool, the cross served as an S^D for a selection response and the circle served as an S^A for the selection response. In contrast, in the presence of

cinnamaldehyde, the circle served as an S^D for a selection response and the cross served as an S^A for a selection response. With sufficient exposure to the conditions, the correct shape should be selected when in the presence of the corresponding odour (Edwards et al., 2022).

In the three-odour arrangement, there was one target odour, cinnamaldehyde, associated with the circle, and two non-target odours, linalool and amyl acetate, associated with the cross. One dog, Indie, was originally introduced to all three odours during the initial training stage. This was reduced to two odours, one target odour and one non-target odour, following the evaluation of the complexity of the experiment and not observing any discrimination among odours in Indie's performance. Thus, the remaining dogs were introduced to two odours during the initial experimental phase.

Each run consisted of 17 trials and could last up to a maximum of 40 minutes; however, no dog exceeded three minutes for a trial. On average, the dogs completed between eight to ten runs a day. If the dog completed a full-day session, then on average they completed between 12 to 15 runs a day.

To introduce a new odour, the dog was required to meet the mastery criteria of achieving an 80% correct response rate for each odour across three consecutive runs. Once established, a new non-target odour, amyl acetate, was introduced. As amyl acetate was a non-target odour, selecting the cross when in the presence of amyl acetate was reinforced; with the presence of amyl acetate serving as an S^D for a selection response and the circle serving as an S^A for the selection response.

Data Analysis

The data analysis process involved both visual and statistical methods. The visual analysis involved generating line graphs to depict the percentage of correct responses for each odour across sessions, alongside bar graphs delineating the distribution of responses

across the touchscreen quadrants over sessions. Interpretation of the bar graphs facilitated insights into potential biases in response distribution.

The statistical analysis was conducted using RStudio (RStudio Team, 2020), using the functions of the ‘stats’ package. This package enabled the calculations of descriptive statistics and 95% binomial confidence intervals.

Chapter 3

Results

Accuracy Rates Across Sessions

Figures 2, 3, 4 and 5 illustrate the percentage of correct responses associated with each odour across sessions for all dogs. Responses exhibited considerable variability across sessions, indicating some fluctuations in performance over time. In general, accuracy was above chance (50%), for C1 and C2 for Sabi, Indie and Amber, and 33.3% for C1, C2, and C3 for Penny, but the accuracy range overlapped with chance for all dogs.

Sabi exhibited high levels of variability throughout the sessions, with her achieving higher accuracy rates for C2 ($M = 66.84$, $SD = 15.31$) than for C1 ($M = 55.34$, $SD = 13.59$). In session 15, it is observed that Sabi achieved the highest percentage of correct responses for both chemicals, with this beginning to decline in session 16. There is a visible decrease in response accuracy from sessions 15 and 16, to session 17. Session 16 signifies a new experimental day, and also a day in which Sabi was administered her arthritis medication, whereas she had not been administered this medication on the experimental day prior.

Indie began with relatively high response accuracy rates, however, this rapidly decreased throughout the middle of the experiment and then began an upwards trend beginning at session 30. Indie achieved higher accuracy rates for C1 ($M = 70.01$, $SD = 15.91$), than for C2 ($M = 59.42$, $SD = 17.71$). Indie had a six-week absence from the experiment, beginning at session 12. Notably, before her absence in sessions seven through ten, Indie almost met the mastery criteria of achieving above 80% accuracy for both odours on three consecutive sessions. However, there is a post-absence decline in response accuracy through sessions 13 to 29, where an increase in variability is observed. Following this decline, an upward trend begins, beginning at session 30 and lasting throughout the remainder of the experiment.

Similarly, Amber also had an absence from the experiment lasting four weeks. Amber had higher response accuracy for C1 ($M = 61.81, SD = 15.74$) than for C2 ($M = 56.18, SD = 17.68$). For Amber, her absence began at session 5 and upon her return a decrease in accuracy is observed lasting from sessions six through nine. There is then an increase in response accuracy shown from sessions ten through 14, with her response accuracy becoming highly variable for the remainder of the experiment.

Lastly, Penny was the only dog to meet the mastery criteria and, therefore, was the only dog introduced to C3. Before this introduction, Penny met the mastery criteria in 13 sessions, with an increase in response accuracy around the eighth session. Upon the introduction of C3, there was an immediate decrease in response accuracy for C1 and C2, however, the response accuracy for C3 began relatively high, at 80% accuracy. The subsequent sessions display a gradual increase for C1 and C3 yet, the response accuracy for C2 remained relatively low at around 50%. Interestingly, for Penny, her response accuracy for C3 was the highest ($M = 69.46, SD = 24.12$), followed by C1 ($M = 61.9, SD = 22.29$), and C2 ($M = 51.13, SD = 20.96$).

Figure 2

Percentage of correct responses across sessions for each odour for Indie

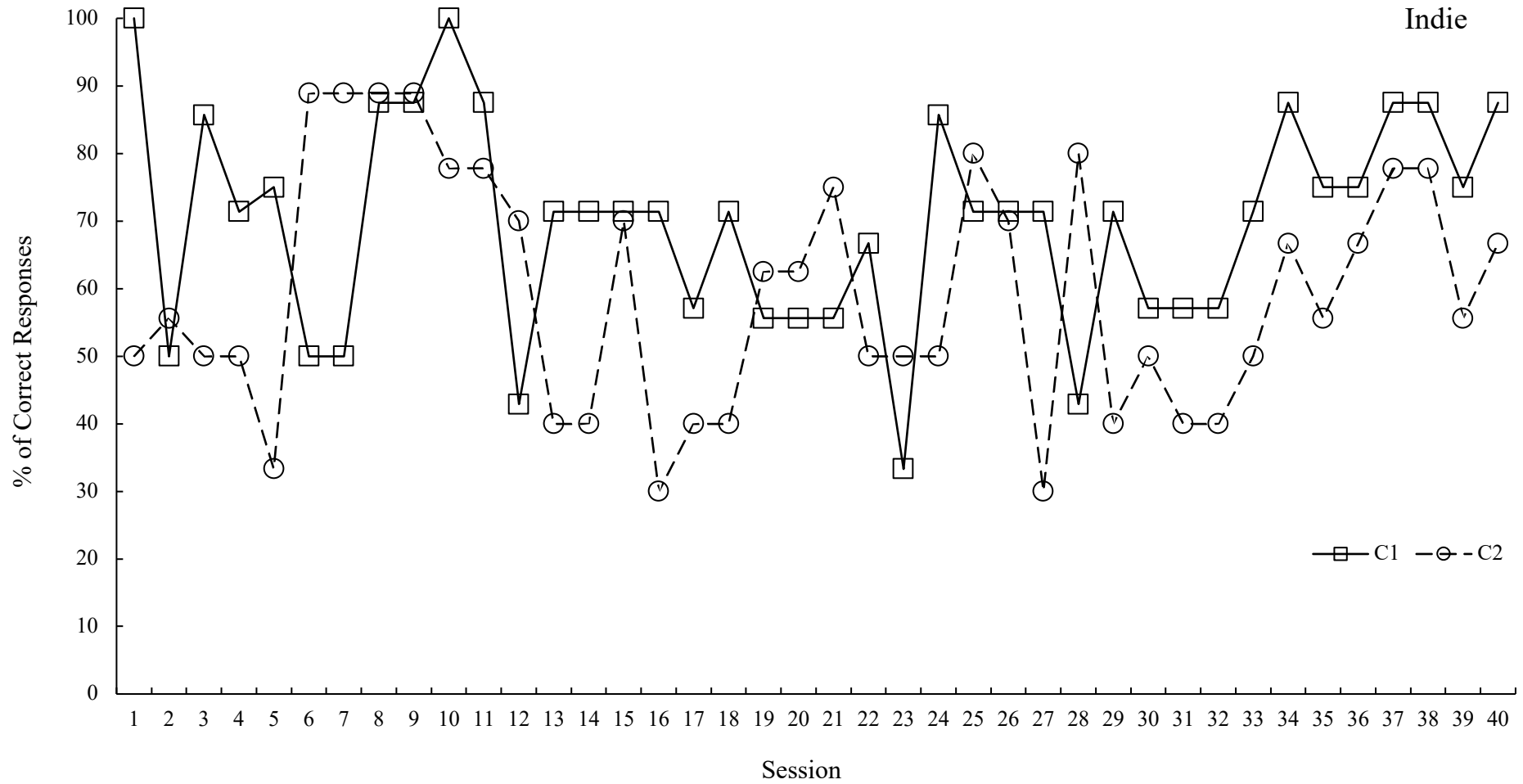


Figure 3

Percentage of correct responses across sessions for each odour for Sabi

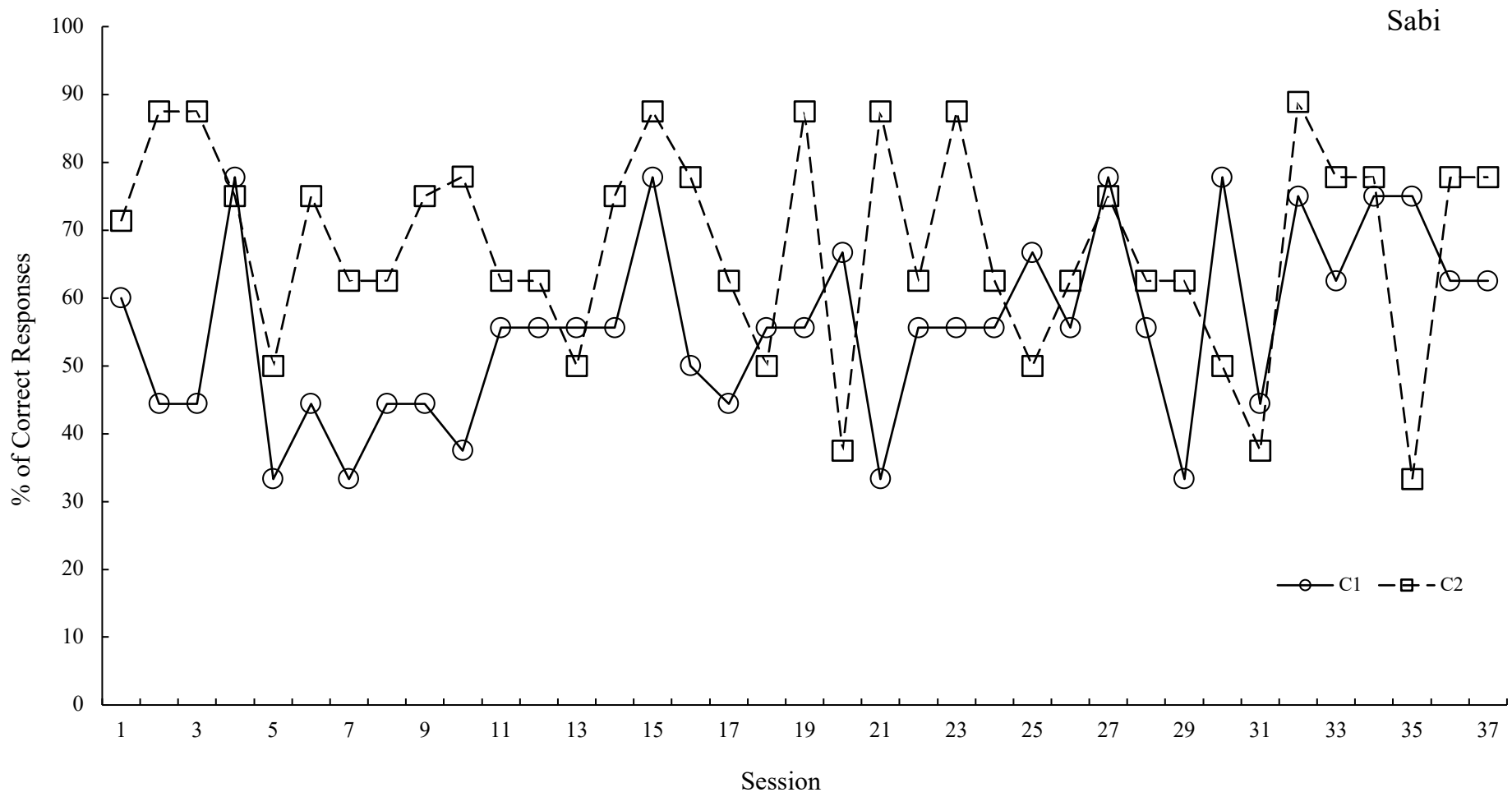


Figure 4

Percentage of correct responses across sessions for each odour for Amber

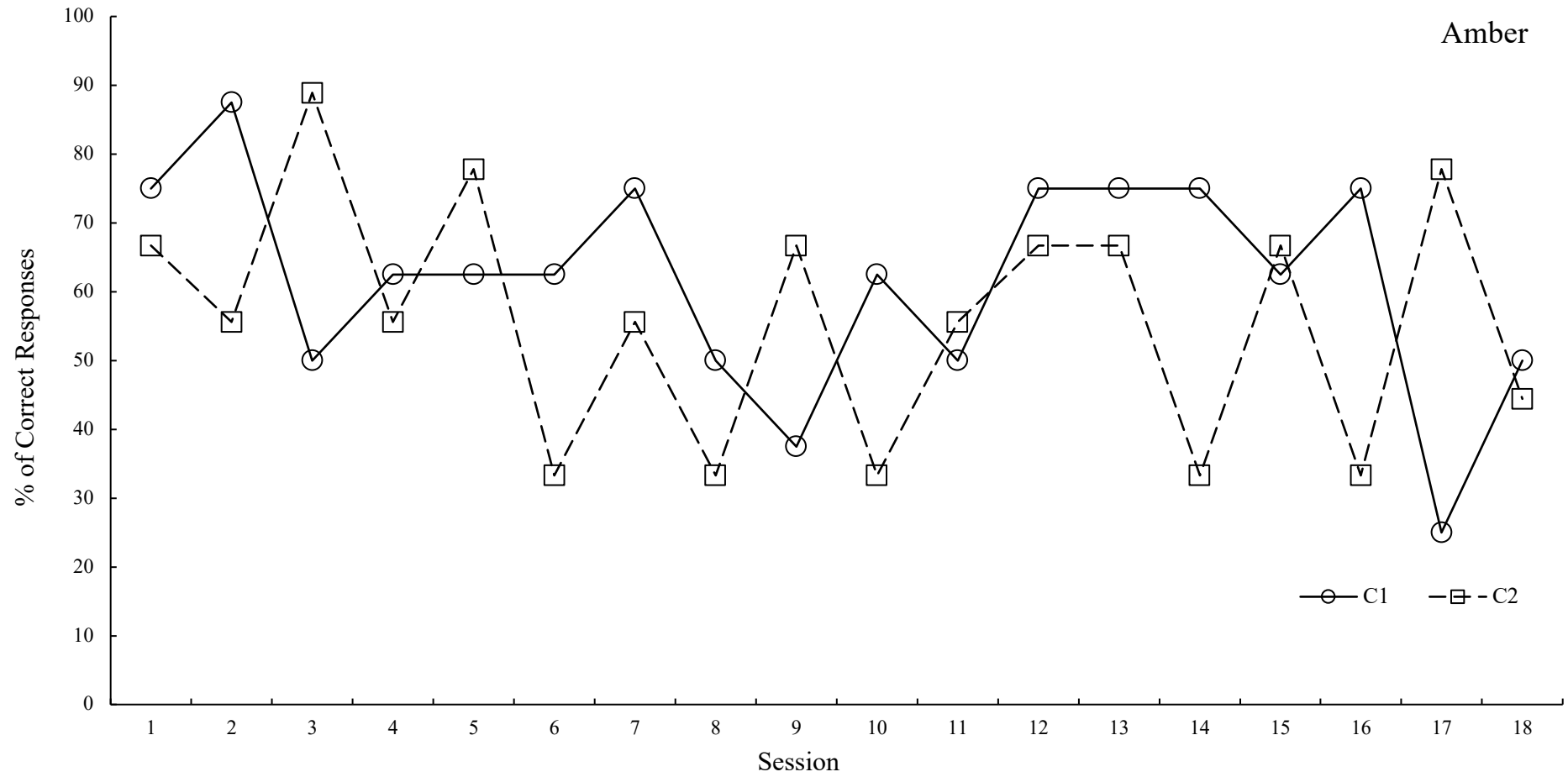
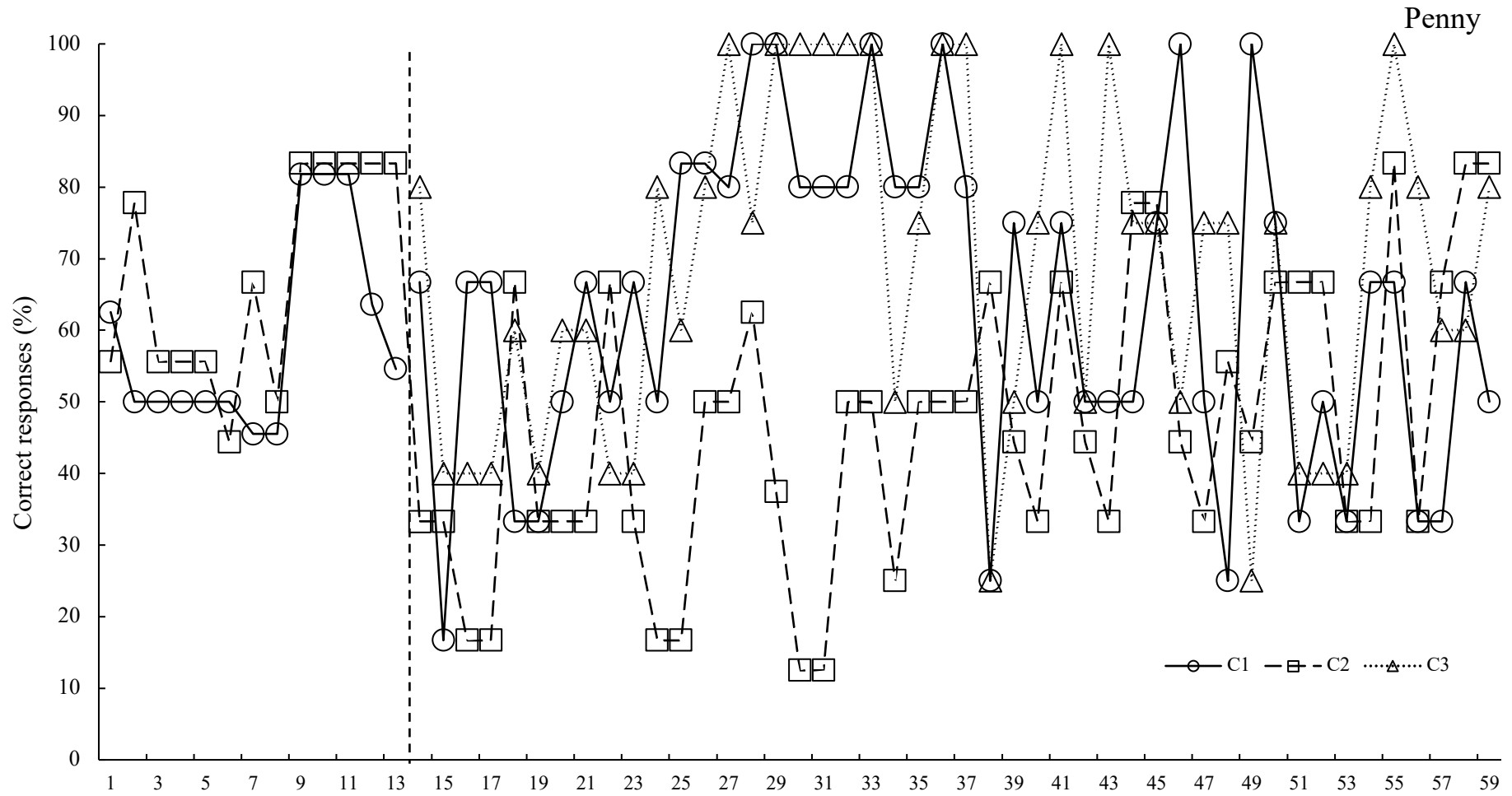


Figure 5

Percentage of correct responses across sessions for each odour for Penny



95% Binomial Confidence Intervals for Each Dog Across Odours

Table 2 illustrates the 95% binomial confidence intervals (CI) for each dog's success rates for odour C1. The 95% CI lower bound and 95% CI upper bound represent the range in which we are 95% confident the true success rate exists. Notably, the confidence intervals for all dogs did not overlap with the 50% chance level for C1. Indie exhibited the highest success rate with a 95% CI of [.65, .75], while Sabi had the lowest success rate [.51, .62]. These findings indicate that all dogs were responding accurately on C1 trials with greater accuracy than chance.

Table 2

95% binomial confidence intervals for C1 for each dog

C1	Observed successes	Total observations	X-squared	df	p-value	95% CI Lower Bound	95% CI Upper Bound	Sample Estimate
Indie	219	311	51.86	1	<.001	.65	.75	.70
Sabi	184	326	5.41	1	.02	.51	.62	.56
Amber	125	192	17.52	1	<.001	.58	.72	.65
Penny	75	125	5	1	0.03	.51	.68	.60

Note. Null probability = .5

Note. Penny's confidence intervals are calculated before the introduction of C3 and the low CI is likely due to the small number of sessions.

Table 3 presents the 95% binomial CI for each dog's success rates for odour C2. Notably, the confidence intervals for all dogs did not overlap with the 50% chance level for C2. Penny exhibited the highest success rate with a 95% CI of [.55, .75], while Sabi [.57, .67] and Amber [.55, .68] had the lowest success rate. Much like C1, These findings indicate that all dogs were responding accurately on C2 trials with greater accuracy than chance.

Table 3*95% binomial confidence intervals for C2 for each dog*

C2	Observed successes	Total observations	X-squared	df	p-value	95% CI Lower Bound	95% CI Upper Bound	Sample Estimate
Indie	218	368	12.57	1	<.001	.54	.64	.59
Sabi	206	331	19.82	1	<.001	.57	.67	.62
Amber	134	216	12.52	1	<.001	.55	.68	.62
Penny	63	96	9.38	1	.002	.55	.75	.66

Note: Null probability = .5

Note. Penny's confidence intervals are calculated before the introduction of C3 and the low CI is likely due to the small number of sessions.

Table 4 presents the 95% binomial CI for each Penny's success rates for each odour following the introduction of C3. Notably, the confidence intervals for Penny did not exceed the 33% chance levels for all odours. For C1, Penny has a success rate of .66 with a 95% CI of [.60, .72]. For C2, Penny had a success rate of .48 with a 95% CI of [.42, .54] and for C3 she had a success rate of .71 with a 95% CI of [.65, .77].

Table 4*95% binomial confidence intervals for all odours following the introduction of C3 for Penny*

Penny	Observed	Total	<i>p</i> -value	95% CI		Sample
	Successes	Observations		Lower Bound	Upper Bound	
C1	182	276	<.001	.60	.72	.66
C2	132	276	<.001	.42	.54	.48
C3	164	230	<.001	.65	.77	.71

Note. Null probability = .33**Quadrant Position Bias**

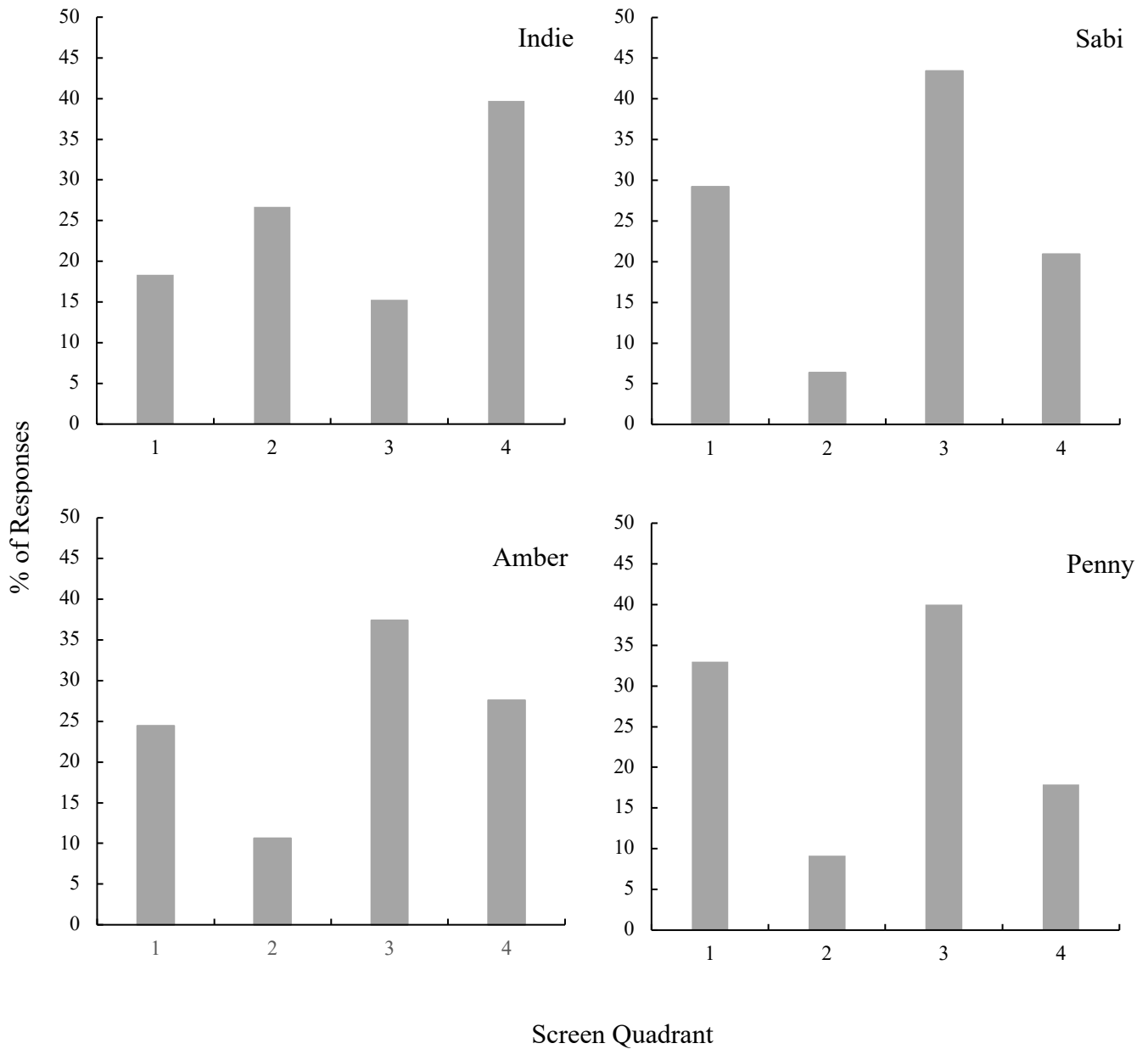
The analysis of the dogs' interactions with the touchscreen revealed distinct preference patterns amongst the four dogs. As shown in Figure 6, three of the dogs exhibited a consistent bias towards the left side of the touchscreen, particularly quadrant 3, situated at the bottom left corner; interestingly all three of these dogs displayed the same proportion of responses made to quadrant 3. This bias was further made evident in their significantly higher response rates to quadrant 3, compared to quadrant 2, with each dog making over twice as many responses to quadrant 3 compared to quadrant 2. For example, Sabi exhibited a response rate four times higher for quadrant 3 than that observed for quadrant 2, demonstrating the disproportionate number of responses made to quadrant 3, shown in Figure 6.

In contrast, one dog, Indie, displayed a preference for the right side of the touchscreen, showing a strong bias towards quadrant 4, located at the top right corner. Across the remaining quadrants, Indie's response selections were relatively equal, with a slight inclination towards quadrant 2. Surprisingly, Indie made the least number of responses to quadrant 3, differing from the remaining three dogs' response selections.

Notably, all dogs made relatively similar proportions of their responses towards quadrant 1, located at the top left side of the touchscreen.

Figure 6

Proportion of responses each dog made to each screen quadrant



Chapter 4

Discussion

Findings

The present study hypothesised that through cross-modal association, utilising both vision and olfaction modalities, dogs would be able to successfully discriminate between multiple odours and produce indications corresponding with the odour that has been detected with greater accuracy than chance.

Overall, the results supported the hypothesis that, for all odours, all dogs exceeded the proportion of successes that would be expected by chance alone. Therefore, we can infer that the scent discrimination observed is unlikely due to chance alone. Comparing our findings to Youngentob et al. (1990), where the rats achieved above chance accuracy, we similarly found that all dogs demonstrated the ability to conditionally discriminate between odours with above chance accuracy. However, it must be noted that all dogs displayed high levels of variability throughout the experiment and fell within the middle range of correct responses per session.

Penny quickly acquired the ability to conditionally discriminate between two odours, meeting the mastery criteria of achieving over 80% correct response rates for both odours across three consecutive sessions. Consequently, she was the only dog to progress to three odours.

Upon the introduction of C3, Penny quickly attained an 80% correct response rate for C3 in the initial trial. The accuracy of responses for both C1 and C2 initially declined with the introduction of C3. Interestingly, in subsequent sessions, Penny's response accuracy for C1 and C3 increased, while her accuracy for C2 decreased. This change likely emerged from an unequal distribution of trials associated with each shape, as reinforcement was more likely to occur when selecting the cross, as two odours were associated with the cross. The

imbalance in trials, where there were more instances of the correct response being the cross than the circle, provides a plausible explanation for the observed increase in response accuracy for C1 and C3, and the corresponding decrease for C2 following the acquisition of C3, as reinforcement was more likely to be administered when selecting the cross.

Both Indie and Amber had a significant absence from the experiment and upon their return, there was an increase in the observed variability in their response selections and a decrease in their response accuracy. Following this period of increased variability, both dogs demonstrated a gradual increase in response accuracy. Indie had almost met the mastery criteria before her absence, as shown in Figure 2 in sessions seven to ten. Upon her return, there was a period of a decrease in response accuracy, followed by an increase in response accuracy and it is plausible that this observed pattern is a result of Indie's absence, leading to a temporary decline in performance. By the end of the experiment, Indie's performance had nearly returned to her pre-absence accuracy levels, as shown in 2. Whilst at the end of the experiment an upward trend was observed in Indie's response accuracy, due to the study being terminated because of time constraints, further analysis was not possible to see if there would have been a continuation of the upward trend and increased performance following session 40.

A similar trend was observed in Amber's performance following her absence with a decrease in response accuracy followed by an increase shortly after. Whilst not as pronounced as Indie's decrease and increase in performance, the observed performance suggests that her absence had a potential impact on Amber's performance.

Another aspect of Amber's performance was her reliance on the experimenter throughout the experiment. This dependence raises concerns about potential unintentional cueing, as the experimenter's presence might have inadvertently influenced Amber's

responses. While there was no explicit evaluation of her independent performance, it is important to recognize the potential impact of unintentional cueing on her response accuracy.

Moreover, Amber's previous training as an assistance dog is imperative for contextualising her behaviour. Her training was centred around interaction with humans, which may have hindered her ability to operate independently in this experiment. This reliance on interaction with the experimenter led the experimenter to use gestural prompts towards the nose port, with her operation of the apparatus then partly under the stimulus control of the experimenter. Whilst the experimenter did not intentionally prompt Amber's response selection, unintentional cueing could have influenced her performance.

Sabi, the eldest among the dogs involved, aged 11, presented a unique set of circumstances beyond the experiment's control, potentially contributing to the variability observed from session to session. For instance, Sabi has arthritis and exhibited day-to-day variations in the intensity of her condition. On mornings when her owner observed an increase in the intensity of her symptoms, such as being slow to get up or sitting on her side, her owner would administer her arthritis medication before she came into the laboratory. This medication, intended to alleviate the associated discomfort, coincided with a discernible decrease in correct responses. Additionally, the observed lethargy in Sabi following the medication administration likely functioned as an abolishing operation of food as a reinforcer.

The experimenter also observed a consistent trend where Sabi exhibited greater motivation in the morning during full-day sessions, where sessions were completed quickly. This gradually subsided in the afternoons, resulting in significantly longer afternoon sessions. This decline in motivation may indicate participant fatigue, a phenomenon recognized in ageing dogs and humans alike (McKenzie & Chen, 2022; Townsend & Gee, 2021). Fatigue, prevalent in demanding environments such as therapeutic or experimental settings, offers a

plausible explanation for the observed session-to-session variability in Sabi (Townsend & Gee, 2021). However, confirming this hypothesis extends beyond the scope of the present study.

Relevant Literature

Drawing on parallels to Youngentob et al. (1990), where the rats achieved above chance accuracy, our findings also found that all dogs displayed the ability to conditionally discriminate between all odours at above chance accuracy. However, the accuracy rates observed in the rats were significantly higher than those observed in the dogs. As discussed by Youngentob et al., like the rats, the dogs were in a forced-choice arrangement. In this arrangement, the dogs had to select one visual stimulus on the touchscreen to progress to the next trial, influencing the number of errors made by the dogs. These forced responses were required regardless of whether the response of selecting one visual stimulus was under the conditional stimulus control of the just-presented odour, which might have led to guessing responses, particularly when sensory evidence was insufficient (García-Pérez & Alcalá-Quintana, 2010). Such responses are often not random but rather reveal a bias towards selecting one option when in a two-choice arrangement. Consequently, these forced responses likely contributed to the errors made by the dogs in each session.

Another observation was the quadrant position bias exhibited by all dogs, where the dogs made significantly more responses to one quadrant than the others. Notably, Indie displayed a bias towards the right side of the touchscreen, while Sabi, Penny, and Amber all displayed a bias towards the left side. These biases may be influenced by the spatial proximity of the scent delivery apparatus to the touchscreen, as the left side of the touchscreen was closer to the scent delivery apparatus and the right side of the touchscreen was closer to the reinforcement.

Interestingly, Youngentob et al. (1990) observed a distinct spatial dynamic bias in rats, where responses were influenced by the perceptual similarities of odours, with the rats making their response selections to tunnels that were associated with odours that were perceptually similar to each other. Despite intentionally selecting odours for their likely perceptual dissimilarity in our study, we observed a different spatial bias, specifically a quadrant position bias. Position biases occur when selections are made based on the stimulus location, becoming problematic when the position of the stimulus exerts more control over the response than the experimenter-intended S^D (Miranda et al., 2022). While Youngentob et al. suggest that these biases may result from experimental disruption or perturbation, similar biases akin to the biases in the present study have also been observed in dogs' performance in other conditional discrimination tasks (see Hogarth & Villeva, 2010; Kangas & Branch, 2008).

In such tasks, position biases often emerge and, if not addressed, persist even when contingencies of reinforcement are in place to support an equal distribution of responses (Kangas & Branch, 2008). This position bias has the potential to endure due to reinforcement under an intermittent schedule of reinforcement. Intermittent reinforcement schedules, as emphasised by Hogarth and Villeva (2010) and Kangas and Branch (2008), contribute to greater persistence in the task. Hence, the dog's consistent selection of one quadrant, even when often incorrect, may have been intermittently reinforced, leading to the maintenance of this response bias.

Lazarowski et al. (2021) indicate that learning a matching-to-sample (MTS) task can be challenging for dogs, often requiring over 1,000 to 3,000 trials before acquisition of the task. Despite this, dogs have previously demonstrated the ability to learn relational concepts (see Byosiere et al., 2017), suggesting their potential for accurate responses in conditional discrimination tasks. Lazarowski et al. outline the importance of providing animals with the

modalities necessary to perform conditional discrimination tasks, as demonstrated by their success in their study. The findings of the present study imply it may be more difficult for dogs to learn an arbitrary MTS task involving visual-to-odour matching compared to Lazarowski et al.'s odour-to-odour identity MTS task. Interestingly, in pigeons, identity MTS tasks were acquired more quickly and with higher accuracy rates than arbitrary MTS tasks (Zentall et al., 2023), indicating that arbitrary MTS tasks are more difficult than identity MTS tasks across species.

Implications

Understanding dogs' abilities to perform accurately in cross-modal discrimination tasks has both theoretical and practical implications. The present study provides insight into dogs' abilities to integrate information from multiple sensory modalities, specifically olfaction and vision modalities, to form a unified perception of their environment. Accurate detection is crucial in a range of detection tasks, such as search and rescue tasks. Therefore, handlers can leverage this understanding to enhance dogs' utility when performing these tasks. For example, in disease detection in the laboratory, dogs utilising information from multiple sensory modalities, such as olfaction and vision, can be used to detect more than one target disease as well as provide information to the experimenter about which disease has been detected.

Furthermore, this study employed unique methodological tools, notably the touchscreen, a novel approach that has not previously been used for cross-modal research with dogs. The use of the touchscreen interface allowed for standardised stimulus presentation and high-precision recording of dogs' responses, thereby streamlining data collection procedures and enhancing the methodological rigour of the study.

Whilst the present study's findings support the hypothesis that dogs are able to learn to respond accurately in cross-modal conditional discrimination tasks and to conditionally

discriminate between multiple odours with greater chance than accuracy, it is important to note that only one of the four dogs reached the mastery criteria and the other three performed better than chance accuracy, yet, they were working with only two odours as they did not meet the mastery criteria to progress to three odours. Therefore, this study provides the basis for future research to further investigate dogs' abilities to learn to respond accurately in cross-modal conditional discrimination tasks. However, the methodological approaches used in this study could be further refined.

Limitations and Future Recommendations

There were several limitations associated with the present study. The demanding nature of conditional discrimination tasks necessitates a higher number of trials for success, as discussed by Lazarowski et al.(2021) However, due to time constraints, we were only able to conduct between 306 to 1,003 trials per dog of the suggested 1,000 to 3,000 trials necessary for dogs to learn conditional discrimination tasks. Notably, Penny completed 1,003 trials and was the only dog to meet the mastery criteria, while the other three dogs completed between 306 to 680 trials. Thus, it is suggested that for the remaining dogs, future research should attempt to increase the number of trials conducted to evaluate if this results in greater accuracy than found in the present study.

Additionally, a notable difference arises when comparing the control of extraneous variables between our study and that of Lazarowski et al. (2021). In their research, conducted with laboratory-housed dogs, they had significant control over factors such as feeding schedules. Conversely, in our study involving household pets, we faced limitations in controlling variables such as daily schedules, feeding routines, and prior training history. For instance, during the initial training phase, it was disclosed that Amber's owner had been feeding her before arriving at the laboratory, potentially reducing the reinforcing effectiveness of food during this phase.

Another limitation of the present study was the initial training procedures used. During the initial training period, two dogs, Indie and Sabi, were trained using the circle to shape using the touchscreen. However, once both dogs progressed to the experimental phase, it was observed that both dogs had a bias towards selecting a circle, which was associated with C2 and they were not observed selecting the cross in equal proportions to the circle. Whilst the shape used for training was later changed to a star for Amber and Penny, it is not possible to determine if Indie and Sabi continued to have a bias towards selecting the circle for the remainder of the study because the software did not record what shape the dog selected on incorrect trials. Therefore, future research should not use the same shape used for shaping during the experimental phase and it is suggested that the data output indicates which shape was the correct response and which shape was selected by the dog for each trial to evaluate if the dog exhibited a bias towards a certain shape.

Building on Youngentob et al.'s (1991) discussion of error responses, the dogs were in a forced-choice arrangement, needing to make a response to progress to the next trial, yet, there is not any indication to the dogs about what the correct response was. Consequently, there was a lack of a correction procedure aimed at minimising errors during the experiment. Hence, future research should consider using a correction procedure. For instance, one approach could involve preventing the dogs from progressing to the next trial upon making an error. Instead, the same odour could be presented again with the stimulus presentation randomised again on the error trial. This method would reinforce the selection of the correct shape with the presented odour. Additionally, changing the configuration of shapes displayed may mitigate position bias, as found by Kagnas & Branch (2008). As trial errors are likely to occur when the correct stimulus is in a quadrant that the dog is unlikely to select, keeping the stimulus fixed and requiring the dog to select that quadrant should help to address the position bias.

Lastly, we recommend minor adjustments to the approaches used in the present study. Future research should consider moving the touchscreen further away from the scent delivery apparatus. Given that dogs' visual acuity is estimated to be around 20/75 compared to humans, positioning the touchscreen at a greater distance would provide them with a broader visual perspective of the configuration of the shapes displayed on the touchscreen (Byosiere et al., 2018). Additionally, creating physical borders that protrude from the touchscreen to delineate each quadrant could enhance the dogs' ability to visually discriminate between the different quadrants and prevent ambiguous responses on the borders between the two quadrants.

Conclusion

The present study demonstrates that dogs can discriminate and produce distinct responses for multiple odours through cross-modal association, achieving accuracy levels greater than chance. However, improvements to the training and evaluation methods have been suggested to potentially increase the accuracy of the dogs' responses. This study provided the initial framework for conditional discrimination tasks utilising cross-modal association with dogs. According to the fundamental principles of learning, it should be possible for dogs to achieve greater accuracy rates than what was observed in the present study with adjustments to the training and evaluation methods.

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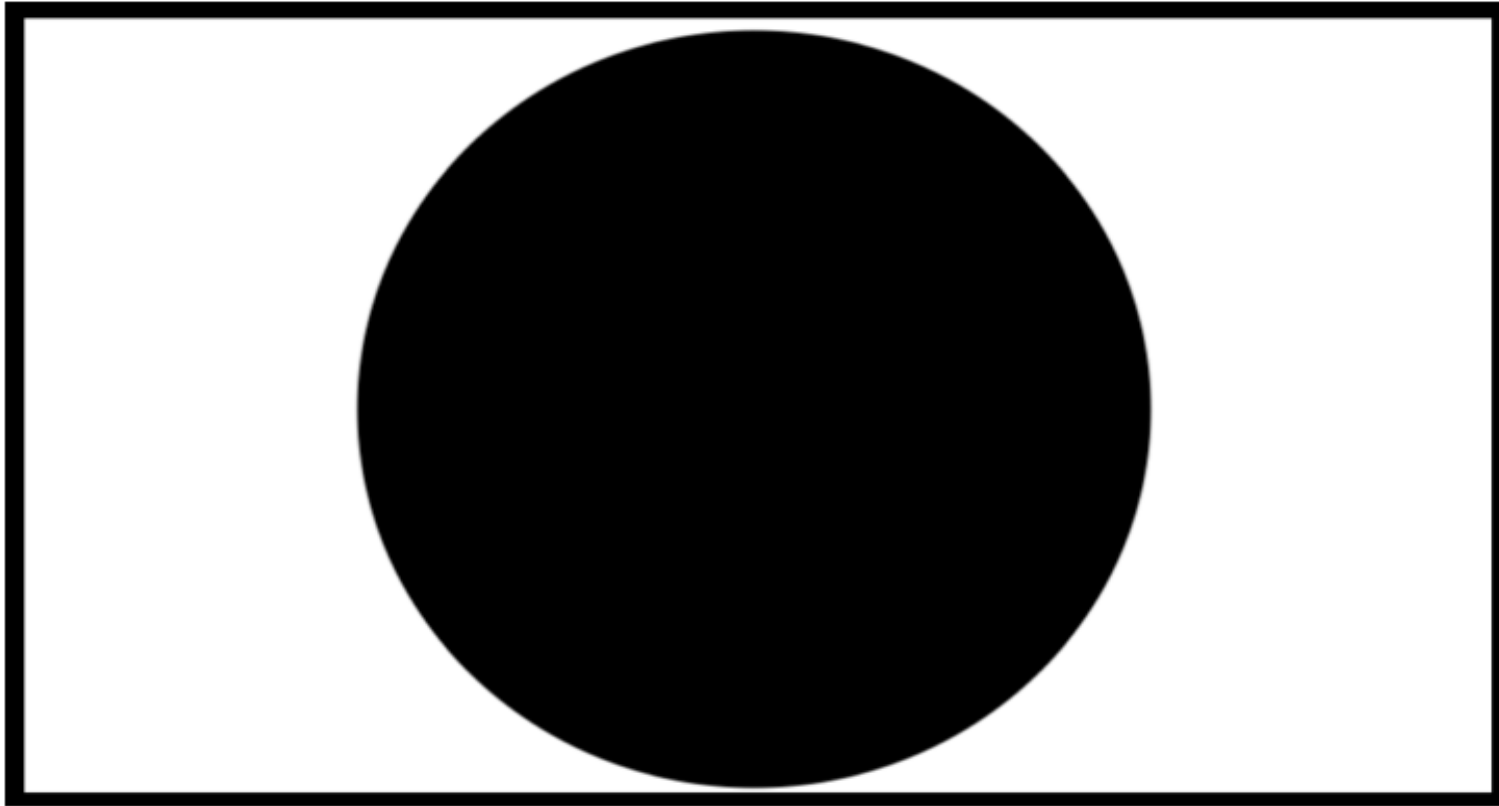
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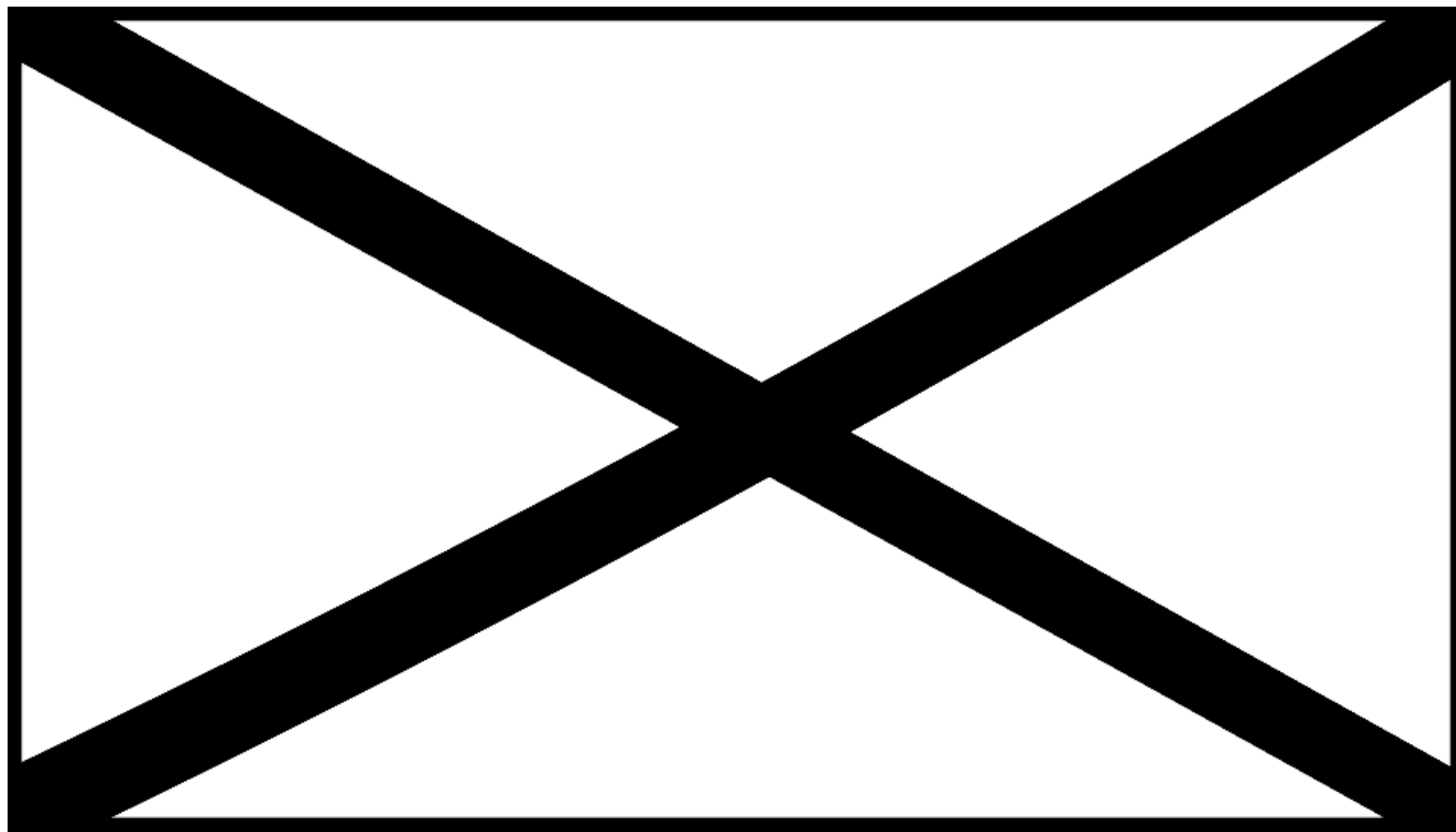
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Appendix A: Image of Circle



Appendix B: Image of Cross



Appendix C: Guidelines for Solution Preparation

Purpose

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

Solution Preparation for Experimental Training Sessions

Solutions are prepared at the chemistry lab located in E block in room E.3.24 on the University of Waikato's Hamilton campus under a fume hood. Covered shoes and personal protective equipment (safety glasses and lab coat) are to be worn on the premises at all times. Disposable gloves are to be worn when handling chemicals and changed between the handling of new chemicals.

Chemicals are prepared individually. New volumetric flasks, 5mL 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 parafilm prior to the preparation of samples.

1. Wear a new pair of disposable gloves
2. Lay down paper towels prior to the preparation of samples. Retrieve a clean set of glassware: a volumetric flask, 5mL beaker, and a 250mL beaker. Place the glassware on the paper towels. Fit the pipette with a clean tip
3. Retrieve the chemical concentrate from the storage cabinet and pour a small amount into the 5mL beaker
4. Fill half the volumetric flask with 50mL of deionised water
5. Use the pipette to extract 25 μ L of chemical concentrate from the 5mL beaker and add it to the volumetric flask. Shake the flask to ensure mixture of the solution Using a 10mL plastic syringe, fill the volumetric flask to obtain 100mL of chemical solution
6. Pour the chemical solution into a Schott bottle. Repeat process to obtain 100mL of chemical solution
7. Seal Schott bottle with parafilm and cover with lid. Place Schott bottle into separate plastic bags to prevent any cross-contamination between chemical solutions
8. Dispose of the pipette tip and change gloves before preparation of next chemical solution
9. Place all volumetric flasks and beakers into a separate holding container. All used glassware will be placed into an acid bath for cleaning.

Disposal of Chemicals

All remaining chemical concentrates that were not used in the preparation of chemical solutions will be disposed of in chemical waste bottles in the chemistry lab. Vanillin,

propionic acid, benzaldehyde, and cinnamaldehyde will be disposed of in separate waste bottles.

Cleaning Procedures

1. Clean the preparation table before any samples are prepared with an isopropanol solution (70% isopropanol, 30% water) and disposable paper towels.
2. Place all glassware used in the preparation of samples in a nitric acid bath for at least 24 hours.
3. Clean the body of the pipette with the isopropanol solution, and disposable paper towels after the preparation of each chemical.
4. If any spillage of solution occurs on the preparation table, clean with isopropanol solution and clean paper towels. Gloves must be changed between cleaning the spillage and the handling of the next chemical solution.

Appendix D: Guidelines for Sample Preparation

Purpose

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

Sample Preparation for Experimental Sessions

The preparation table is cleaned with isopropanol (IPA) solution and disposable paper towels before sample preparation begins. Use a random number sampler to ensure that all chemical samples are prepared in a randomised order every session. The required amount of parafilm is to be cut before every sample preparation.

1. Wear a new pair of disposable gloves
2. Place paper towels on the preparation table
3. Label vial using a marker
4. Place vial on the paper towel
5. Uncap the Schott bottle with the desired solution and dispose of the parafilm and gloves
6. Using a new pair of gloves, retrieve a new pipette tip from the storage container and fit onto the pipette
7. Fill the vial with 2mL of solution
8. Seal Schott bottle using a piece of parafilm and put the lid on the bottle
9. Using a new pair of disposable gloves, clean the body of the pipette before preparing the next sample. Dispose of gloves when done.
10. Repeat procedure for all desired chemicals

Disposal of Chemicals

The chemicals that were used in the experimental sessions are poured into separate Schott bottles and disposed of in the chemistry lab located at E3.24. Vanillin, propionic acid, benzaldehyde and cinnamaldehyde are disposed into four separate waste bottles. All other chemicals are disposed into the same waste bottle labelled "*non-chlorinated and non-halogenated solvents.*" Deionized water is disposed of in the sink.

Cleaning Procedures

1. Clean the preparation table before any samples are prepared with an isopropanol solution (70% isopropanol, 30% water) and disposable paper towels.
2. Place all glassware used in the preparation of samples in a nitric acid bath for at least 24 hours.
3. Clean the body of the pipette with the isopropanol solution, and disposable paper towels after the preparation of each chemical.

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

Appendix E: Guidelines for Scent Detection Work Using an Automated Scent Delivery

Apparatus and Touchscreen Apparatus

Purpose

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

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 three cameras to monitor the dog. The computer(s) used to control the apparatus and monitor the dogs should be positioned in the adjacent room.

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 to the next stage of training. However, some dogs may require additional criteria before progressing to the next stage of training. Keep sessions under 10 minutes.

Introduction

Once the dog has been habituated into the training environment, the experimenter can proceed with the training sessions. During training processes and shaping, 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.

Conditioned Reinforcer Establishment

The experimenter should enter the experimental room with the dog and stand to the side of the apparatus, preferably the side closest to the door. The experimenter 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 experimenter should avoid the dog's gaze to minimise unintentional cueing. This will then facilitate the fading of the experimenter'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 if 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.

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 comfortable and reliably placing their nose into the port far enough so that the segment flap is open, the apparatus should then be stocked with odour samples and switched on. The dog's configuration file on the computer should be edited to the arrangement of odour samples on the carousel. The indication response time should be set to 1000ms and the observation response time should be set to 500ms. 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 (17 samples) is complete at the 1000ms threshold is complete, the threshold should be increased in 100ms to 500ms intervals until the threshold is at 1500ms. Once a run at 1500ms is completed, move on to the next training step.

Shaping of Touchscreen Use

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 touchscreen. An appropriate topography for using the touchscreen should be selected depending on the behavioural tendencies and size of the dog (e.g., using their nose or paw on the touchscreen). 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 touchscreen 10 times without the use of prompts and the dog has been reinforced using manual activation of the feeder, move on to the next training step.

Discrimination Training

Load the apparatus with eight segments, with two in places 1 and 2, and the other six placed to balance the apparatus. C1 (Linalool) should be placed in segment 1, and C2 (amyl acetate)

should be placed in segment 2. The arrangement of samples should then be updated in the dog's configuration file.

With the apparatus being switched on, bring the dog into the experimental room with the experimenter standing beside the apparatus and closest to the door if possible. If the dog does not respond to the apparatus within 20 seconds, prompt the dog as required. When the dog approaches the first sample, allow for 20 seconds before prompting to see if the touchscreen 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.

Once one run has been achieved without any prompting, the arrangement of samples should be randomised in the following sessions and updated in the dog's configuration file. The same randomisation pattern can be used up to a maximum of 5 sessions in a row before it is needed to be randomised again. Continue until the correct response rate is above 80% without the use of prompts.

Once this has been achieved, the experimenter should gradually remove themselves from the room and systematically increase the threshold in 100ms to 500ms increments once the dog is working successfully and independently. The indication threshold should be increased until the target threshold is reached, which is around 5000ms as it is generally the optimal threshold based on prior research but this may vary depending on the dog and application.

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 the 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 touchscreen during discrimination training, conduct another touchscreen shaping session).
- If the dog continues to perform poorly, consult with your supervisor. The dog may need to cease participation in the study.

Guide for Shaping Sample Port Entry

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 startle the dog to begin with.

2. Reinforce for moving further away from the feeder, until the dog is reliably approaching the side of the room near the apparatus.
3. Reinforce attending to the apparatus (putting their nose near/on any part of the front panel of the apparatus).
4. Reinforce nose near port.
5. Reinforce nose in port.
6. Reinforce nose touching and opening the flap (this is indicated by the noise the flap makes when it closes).
7. Reinforce pushing the flap further inwards
8. Turn the apparatus on and it will now make a continuous beeping noise when the port beam is broken.
9. Continue to reinforce beam breaks and pushing the flap inwards, until the dog is fully opening the flap and breaking the beam for 300ms.

Guide for Shaping of Touchscreen Use

1. Turn the apparatus off and do not load the segments with samples.
2. Reinforce any movement towards the touchscreen.
3. Reinforce any movement of the nose (as appropriate) towards the touchscreen.
4. Using the training software, reinforce any paw or nose (as appropriate) contact with the touchscreen where a shape is displayed.