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Does Odour Complexity Alter The Influence of Intermittent Reinforcement on Dogs' Scent Detection Performance?

A thesis

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of the requirements for the degree

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Abstract

Scent detection work exists in many fields such as medical research/diagnostics and law enforcement, in which canines have proven success in detecting biological and non-biological scents. Their olfactory capabilities allow them to detect trained odours while ignoring non-trained odours existing in the environment. This study aimed to determine if odour complexity altered the influence of intermittent reinforcement on dogs' scent detection performance. Using an Applied Behaviour Analysis framework, dogs were trained to use a carousel and be exposed to odours varying in complexity. This study used a within-subject, cross-over design where dogs completed one condition before switching to the other condition. The Complex Condition consisted of one target odour comprised of three chemicals and deionised water and nine non-target odours with overlapping target components and deionised water. The Simple Condition consisted of one target odour comprised of one chemical and deionised water and a blank segment that served as the non-target. Data was collected using custom-designed software for every session. Potential sequence effects were observed which might have impacted the overall results however, this cannot be confirmed. Longer session times were also observed for the Complex Condition compared to the Simple Condition. This indicates that although a sequence effect may be responsible for some of the results, the increased complexity of odours in the Complex Condition likely impacted dogs' scent detection performance. It may be helpful for future research ideas to replicate the study with applied targets and try to recruit more dogs.

Acknowledgements

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Lastly, I would like to thank my family for their support over the year. Thank you for continuing to believe in me and motivate me. Thank you for enduring all the videos and pictures I sent you over the year of the funny moments I had with my dogs.

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Chapter 1

Introduction

Canines have proven useful in practical fields such as medical research and diagnostics, law enforcement, conservation efforts, and more. Canines have proved highly effective in detecting non-biological scents, such as explosives and drugs, and biological scents such as human odours and animal scents (Browne et al., 2006). A canine's olfactory capabilities that enable them to successfully locate their targets whilst ignoring numerous non-target scents encountered in their environments, such as airports, are claimed to be better than those of instruments according to Browne et al. (2006). According to Lazarowski et al. (2020), research on scent-detection dog performance has played a crucial role in understanding their olfactory capabilities and behavioural characteristics improving training, expanding deployment practices, and advancing applied canine technologies. The specific behavioural requirements associated with scent-detection tasks are important determinants of scent-detection performance (Edwards et al., 2022). Intermittent reinforcement is often used in some scent detection research due to the nature of their studies not being able to work under continuous schedules of reinforcement (e.g., the use of blind samples).

Intermittent reinforcement (IR) is when the reward is delivered only sometimes when a behaviour occurs (Tarbox, 2017). During the initial acquisition of a target, continuous reinforcement schedules are utilised (Hall, 2017) however, intermittent schedules of reinforcement can be leveraged for maintenance. In practical applications of an experiment, it is a necessary condition for dogs to be exposed to and work under IR, as this can strengthen their behaviour against extinction (Davey, 1998). According to Ferster and Skinner (1957) shifting from continuous schedules of reinforcement to intermittent schedules of reinforcement is important for ensuring that the behaviour that was trained becomes resistant to extinction resulting in the animal's behaviour persisting in the absence of the reinforcement (reward). Graham et al. (2010) explains how this is important for practical settings in scent detection work, specifically during long searches where the handler cannot be certain if the target is present. Problems can arise when an incorrect target is reinforced. This is especially important in situations where the handler does not know the status of the samples and, as a result, does not know whether the dog is indicating correctly (Ellis et al., 2019). Accidentally reinforcing a non-target can cause a resurgence of previously extinguished behaviours, resulting in a decline in accuracy and an increase in false indications (Shahan & Sweeney, 2011).

According to Sargisson and McLean (2010) a way to alter an animal’s response accuracy is by manipulating reinforcement ratios. This was done by manipulating reinforcement rates for targets (hits) to investigate the impact on dogs’ scent detention performance. This indicates that increased reinforcement rates improve a dog's sensitivity instead of producing a response bias. Sensitivity refers to the dog’s ability to discriminate between positive and negative samples. This study also found that at a medium reinforcement rate (intermittent reinforcement), the dog's false alarm rate was at its lowest compared to a high reinforcement rate (continuous reinforcement).

Using IR in scent detection training can pose challenges as seen in research by Crawford et al. (2022). Dogs were exposed to breath samples from people with and without lung cancer under reinforcement schedules to shape their responses. The study evaluated the usefulness of specific analytical techniques to determine the appropriate time to transition dogs from training to testing using an automated apparatus. Dogs’ accuracy declined with the introduction of IR resulting in IR being discontinued until accuracy increased again. During the training phase, IR conditions were utilised to simulate blind testing conditions.

The study by Ellis et al. (2019) was set up to determine changes in reinforcement rate and its impact on the scent detection performance of rats. The study evaluated African pouch rat's ability to discriminate between target and non-target odours. Ten chemicals commonly used in the fragrance industry were used. One of these chemicals was used as the target scent and the nine other chemicals as the non-target scents. Positive reinforcement (food) was used to strengthen correct indications. Continuous reinforcement schedules were used for the initial training stages until the rats displayed accurate target acquisition. Intermittent schedules of reinforcement were then introduced to strengthen behaviours against extinction. Negative samples and overall samples increased and the reinforcement rate for correct indications decreased. Results demonstrated that rats effectively worked under conditions of IR, however when the target was only present in 2% of the trials, their hit rate began to suffer and decreased. This suggests that when introducing intermittent schedules of reinforcement, the handler needs to consider the ratio of reinforcement to prevent a decline in performance.

Edwards et al. (2021) evaluated the influence of reinforcement rate and signal presence on detection accuracy using domesticated hens. As the study progressed, the domesticated hens were reinforced for a percentage of their correct responses. The aim was to determine how the availability of a signal and the reward rate affect the hens' accuracy and decision-making. This is supported by Bouton's (2004) review and integration of the behavioural literature on Pavlovian extinction and Hall's (2017) investigation of continuous vs intermittent reinforcement on a dog's performance during scent detection tasks. Both studies stated that conditioning with partial reinforcement schedules (intermittent reinforcement) created a slower loss of responding in extinction than conditioning with a continuous reinforcement schedule, suggesting an increase in dogs' long-term performance stability.

The effects of IR might also be influenced by the complexity of the task and odour. In Crawford et al. (2022), the complexity refers to the overlapping features between target and non-target odours, making discrimination more challenging. According to Hall (2017) IR can lead to persistence in behaviour thus making it resistant to disruption, however Crawford et al. (2022) found that complex stimuli combined with IR resulted in an initial decline in accuracy, followed by a slower rate of recovery through sessions. This indicates that task complexity combined with IR schedules might have an impact on the outcome of the performance. The concept of stimulus complexity is important for understanding scent-detection dogs' olfactory discrimination capabilities.

For this present study, the term complexity referred to overlapping between target and non-target chemicals. Thomas-Danguin et al. (2014) referred to heterogeneous and homogeneous chemical mixtures. Homogeneous refers to a single odour being perceived from the mixture and heterogeneous is when several odours are perceived from the mixture. A homogeneous mixture is perceived as a completely new entity and be referred to as configural however, some components of the heterogeneous compound can be detected individually thus being referred to as elemental. Thomas-Danguin et al. (2014) explain complex mixtures as including more than two odorants. Samples containing one odourant are perceived as 'simple' and easier to process due to having fewer components however, samples containing multiple odourants are perceived as 'complex' due to their overlapping features, making it harder to detect a specific odour. A higher odour complexity might reduce a dog's sensitivity, making it harder to discriminate between the target odour and background noise (overlapping non-target components).

A typical approach to obtaining meaningful data from scent-detection dogs is to train dogs to make specific indication responses when they encounter a target and then move on to the next possible target without making indications in the presence of a non-target (Edwards et al., 2022). According to Hautus et al. (2021), in Signal Detection Theory a dog's response can be categorised into 'false alarms' (indicating a non-target as a target), 'correct rejections' (correctly rejecting the non-target), 'hits' (correctly indicating the target), and 'misses' (failing to indicate a target).

Signal detection theory (SDT) can be defined as a theoretical framework developed to analyse behavioural responses of organisms performing a sustained task in a laboratory (Sumner and Sumner, 2020). SDT can be a useful framework for further analysis of observer accuracy (Lerman et al., 2010). An example provided by Sumner and Sumner (2020) is using SDT in experimental psychology when testing the ability of a subject to detect a short tone (beep) in a background of white noise. The study required the subjects to decide if a tone was present, with 50% of trials only having white noise and 50% of the trials having tones presented randomly. Results showed varied performances according to Sumner and Sumner (2020), with the subject's results varying from a 100% accuracy rate when the amplitude tone was larger to 50% when the amplitude was smaller as the perceptions became ambiguous. SDT assumes that the animal will respond according to each response criterion (Sargisson & 2010). This assumes that an animal will respond according to an internal threshold - the point at which the animal determines if the stimulus (an odour) is strong enough to be categorised as a signal or background noise. This internal threshold is shaped by the animal's prior experience and training.

Signal detection allows us to evaluate the dog's ability to recognise and respond to the target odour (signal) among other non-target odours (noise). Factors that can influence signal-to-noise ratio are the concentrations of the target odours vs non-target odours, which in this present study are kept constant, and the non-target odours overlapping with target odours. When dogs encounter the target odour, it serves as the discriminative stimulus as a correct response will result in reinforcement in the form of dry kibble. Signal detection involves dogs indicating or not indicating in the presence or absence of a target. Four possible signal detection outcomes; true positives, false positives, true negatives, and false negatives, are produced by those two behavioural responses (Concha, Mills, Feugier, Zulch, Guest, Harris & Pike, 2014). For the purpose of this study, the signal vs noise ratio differs between conditions. For the Complex Condition, the signal-to-noise ratio was low making it harder for the dogs to identify the target. For the Simple Condition, the signal-to-noise ratio was increased to make it easier for the dogs to detect the target odour.

1.1 Research Aim

This study aimed to test if odour complexity altered the influence of intermittent reinforcement on dogs' scent detection performance.

1.2 Hypothesis

H1

We hypothesise that an increased odour complexity will influence dogs' scent detection performance under intermittent reinforcement.

H2

We hypothesize that dogs will perform worse in the Complex Condition compared to the Simple Condition under the effects of intermittent reinforcement, shown by longer task completion times, lower accuracy in scent detection, or failure to meet performance criteria.

Chapter 2

Method

2.1 Subjects

2.1.1 Dogs

Eight dogs were screened for participation in the study. Out of the seven that met the inclusion criteria (see Table 1), four dogs completed the study. The initial screening included the effectiveness of dry kibble as a suitable reinforcer for each dog, the dog's suitability for being housed for half a day and working in a laboratory environment. Two dogs were eliminated within their first week of training due to sustained anxiety-related behaviours inside the working room and the two other dogs were eliminated before training commenced due to owner availability.

Table 1

Participant Dog Profiles

Name	Sex	Age at recruitment	Breed
Ben	M	4 years	Labrador
Bayley*	F	15 months	Labrador
Memphis	M	14 months	Mastiff x American Staffy
Salt	M	6 years	White Shepherd
Ngahere*	M	4 years	Sharpei x Pitbull
Mac	M	2 years	Labrador
Evie	F	11 months	Spoodle
Churro	M	2 years	Cavoodle

Note: Dogs with bold names completed the study

* Dogs were not neutered.

2.1.2 Recruitment

Dogs were recruited through the University of Waikato's Instagram and Facebook platforms, a Hamilton Dog Owners group on Facebook, word of mouth from current participant owners, flyers handed out at dog parks, and posters around the University of Waikato Campus. The owners were sent an email and filled out paperwork regarding information about the dog/s such as their name, age, breed, vaccination status, food preference, behaviours around food, days and times they are available, vet information, and contact information for the owners. After this, the dogs were assigned to current projects according to lab running days and dog owners' availability.

2.2 Routine

Sessions took place Wednesday, Thursday, and Friday mornings from 8:30 am to 12:30 pm. The number of sessions that took place per dog a day varied from one to seven. This was due to equipment maintenance problems that arose or if some dogs could not make sessions which resulted in other dogs having more time to complete more sessions however, three sessions were the average number of sessions occurring in a day.

2.3 Eligibility criteria

Dogs had to be food motivated, vaccinated, non-aggressive around food and other people, and able to stay in the lab without their owner present and not display signs of anxiety-related behaviours. Dogs also had to be comfortable in kennels as they were not allowed to mingle unless they were from the same household/family.

2.4 Ethics Approval

Approval for this experiment was obtained from the University of Waikato Animal Ethics Committee (protocol #1193).

2.5 Materials

2.5.1 Chemicals

See Table 2 for information regarding the chemicals and the smell each chemical used was perceived to have. The chemicals and their concentrations were chosen based on previous study guidelines so that the scent was detectable but not strong to a human. See Appendix I for more information on the protocols for mixing chemicals in the laboratory and Appendix K for cleaning used vials. The ratio of chemicals to deionised water was 30µl:100ml. In the case of two chemicals being used the ratio of chemical to deionised water was 15µl:15µl:100ml and if three chemicals were used the ratio was 10µl:10µl:10µl:100ml. See Appendix I and Appendix J for more information on the process of making the Simple Condition and Complex Condition target and non-targets.

Table 2

Chemicals Used in Simple and Complex Conditions

Chemical	Chemical Abbreviation	Smell	Vapour Pressure at 25C (mmHg)
	Complex Condition		
Amyl Acetate	A	Banana	5.17
Hexanoic Acid	B	Cheesy/waxy	0.0435
Cinnamaldehyde	C	Cinnamon	0.0289
Benzyl Acetate	D	Jasmin	1.425
	Simple Condition		
1-Octanol	Simple 1-Octanol	Rose/Lemony	0.07

2.6 Complex Condition

The target mixture consisted of three chemicals ABC and deionised water, as shown in Table 3. Components from the target mixture were used to create non-targets. Benzyl Acetate was used as a non-target component. The non-target mixtures consisted of either two components of the target mixture (i.e. AB), and Benzyl Acetate (i.e. ABX), or one target component and the non-target component (i.e. AX). Nine non-target mixtures were created and labelled AB, BC, AC, ABX, BCX, ACX, AX, BX, and CX. Table 3 shows how the target and non-targets were numbered.

Table 3

Target and Non-Target Compounds and Their Assigned Numbers

Compound	Assigned Number
Target Compound	
ABC	1
Non-target Compounds	
AB	3
AC	4
BC	5
AX	6
BX	7
CZ	8
ABX	9
ACX	10
BCX	11

2.7 Simple Condition

1-Octanol was used as the target chemical. A blank segment was used as the non-target. See Table 2 for a description of the Simple target.

2.8 Equipment

2.8.1 Carousel

The carousel, see Figure 1, can fit up to 17 segments. For this study, only 11 segments were used. The segments were placed on numbers 1-7 for the Complex Condition and 10-13 for the Simple Condition. Each segment had a square holder indicated by the red circle in Figure 1. This was used to hold the vial in place. The dogs placed their nose through a port as shown in Figure 2. Figure 3 shows the segment flap the dog's nose went through when they placed their nose through the port. Figure 2 shows the lid that was placed on top of the segments and the lever attached to the right side of the front panel indicated by the red circle. The lever was a tool for the dogs to use to advance to the next sample. Dogs had to press their nose against the lever to achieve a 'clicking' sound indicating a successful lever press. The lever was an omnidirectional switch that could be activated in various ways by the dogs (e.g., brushing against it or pushing it with their nose).

The Carousel had two different LED colours that were displayed on the front panel shown in Figure 2. The lights were to indicate different actions, and this was for the benefit of the researcher to know what was happening whilst watching from the cameras. The white light, partially displayed in Figure 2, indicated the carousel was ‘ready’ for the dog to start and continued to show when the dog had their nose in the port, the green light indicated a correct response, and the cue of the feeder, the blue light indicated the carousel was turning/moving to the next segment. The red light indicated the dog was putting its nose through the port whilst the carousel was moving, and it was not ready for the dog. When this happened, the carousel stopped immediately until the dog took their nose out of the port. A double ‘beep’ noise was the cue for the dogs that the carousel had moved to the next port and a continuous beep sound was made for the duration of the dog's nose in the port. If a dog inserted their nose into the nose port while the carousel was still turning, then no continuous beep noise was made and the carousel stopped. This would require the dog to remove their nose from the port completely and wait for the carousel to finish moving to the next segment.

Figure 1

Display of the Vial Holder and Carousel Setup with Segments

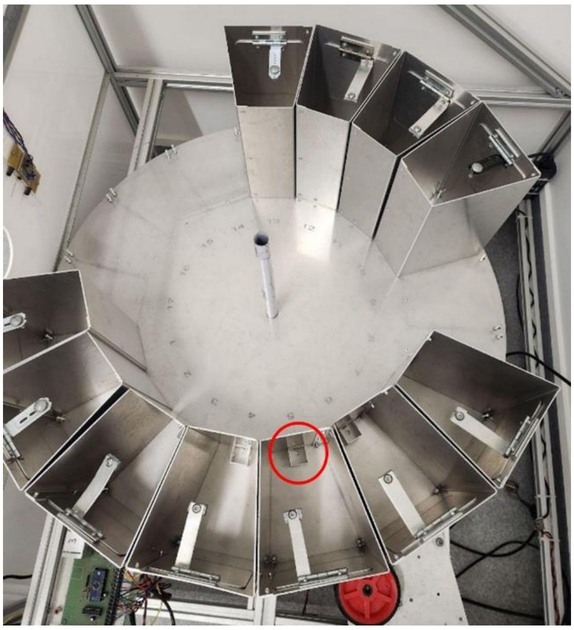


Figure 2

Display of the Lever and a Dog Placing Their Nose Through the Port

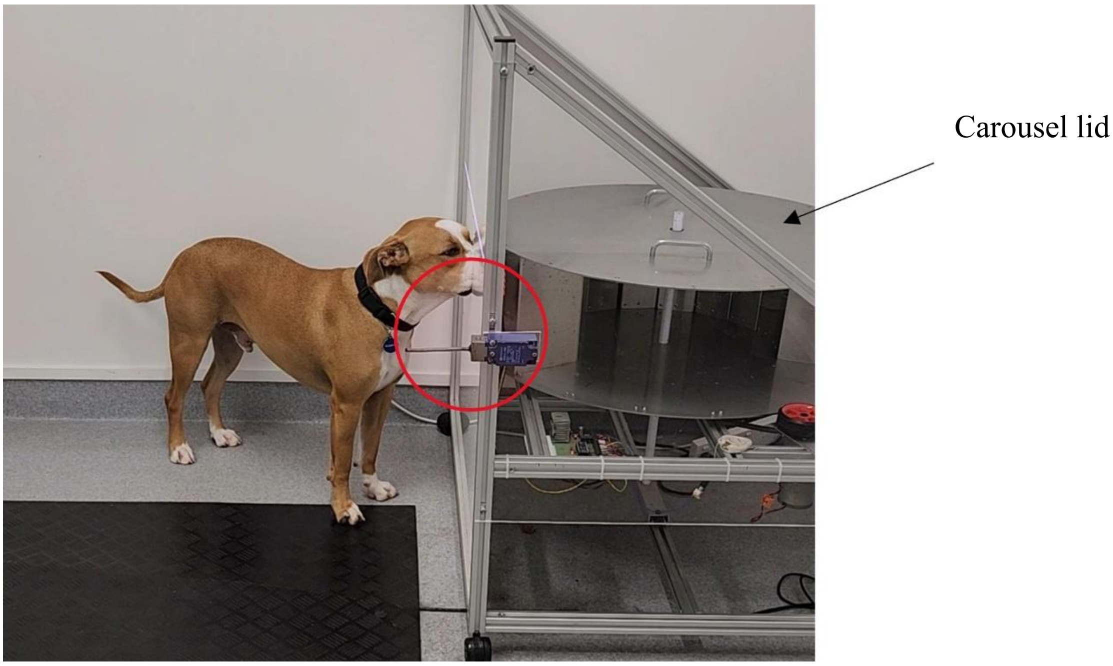
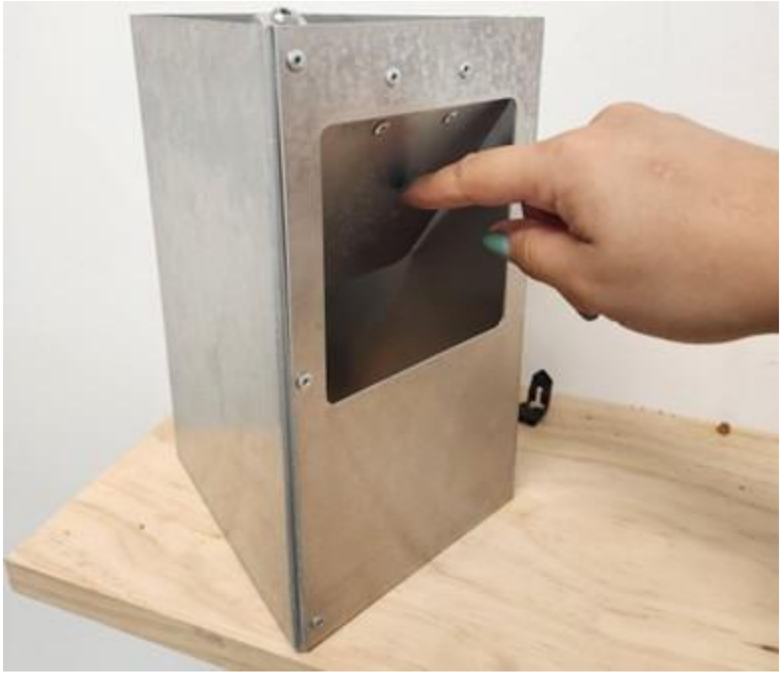


Figure 3

Front and Side View of Segment Flap



2.8.2 Dog Feeder

As shown in Figure 4, the commercially available Treat&Train Remote Reward Dog Trainer dog feeder was mounted on a shelf to the right of the carousel and delivered the dry food via a pipe onto the floor for the dogs. The feeder was mounted onto the shelf due to previous projects where the dogs attempted to get food out of the feeder. The food used was dry kibble either beef or lamb flavoured. Large kibble was initially used in the shape of a triangle however, due to ongoing problems getting stuck in the dispenser it was changed to smaller round kibble, and the number of kibbles being dispensed changed from one biscuit to two biscuits.

Figure 4

Dog Feeder Mounted onto the Shelf in the Laboratory Room

2.9 Cameras

4x video cameras (Logitech® 2 MP HD Webcam C600) with built-in microphones were placed around the room to get different angles of the dogs working. This allowed the researcher to observe the dog whilst in a different room. Cameras were also used for any maintenance issues that arose so that the origin of the problem could be depicted.

2.10 Computer

A Dell computer was used for the experiment. To record and save each session, cameras were placed in the experimental room and could be watched from the computers in the office area of the laboratory. This allowed researchers to be outside the experimental room and watch the dog work independently. A custom-designed software was used to control, display, and record real-time data from the apparatus. Each dog was given a file number for individual programming called configuration files. The data in these files could be modified if needed. Information such as sample status (positive vs negative), sample display order, number of kibbles per reinforcement, the minimum amount of time required to record the observation of a sample (500ms), and the duration of time required for a positive indication response. Event Files, linked to each dog's number, stored each session's data for further data analysis.

2.11 Carousel training

2.11.1 Shaping

Port shaping was done by providing the dogs with a reinforcer (dry kibble) every time they walked or looked in the direction of the front panel of the carousel (there were no segments placed on the carousel during this phase of shaping). Gradually, as the dogs learned going near the front panel resulted in a reinforcer, they were then provided with a reinforcer every time their nose would get near the port. Once the dogs learned that behaviour, they were provided a reinforcer every time they placed their nose in the port. Lastly, for the port shaping, the segment was placed on the carousel and the dogs were provided with reinforcement when they held their nose in the port for a short period, < 5 seconds. Reinforcement was not given if a dog's nose was not observed to be pushing the segment flap open.

Lever shaping was introduced on a new day once the dogs had successfully passed the port shaping (3x unprompted). The lever shaping procedure mirrored the port shaping procedure used during the initial introduction to the apparatus. Once the dogs began holding their noses by the lever, reinforcement was only given when they pushed the lever, producing a clicking noise. The pass criteria for the lever shaping were 10x unprompted lever presses.

2.12 Discrimination training

Discrimination training was introduced once the dogs completed the port shaping and lever shaping. Ben had prior carousel training as he participated in a previous project that employed the carousel, so he went straight to discrimination training. Sessions were 12 trials long with a target: non-target ratio of 50:50 until 80% or higher for the correct rejection rate and the hit rate was achieved for two out of three sessions occurring on the same day. A trial refers to the evaluation of one segment and a session refers to a collection of trials. After this, the number of trials was increased to 20 with the ratio of targets: non-targets being 8:12. Once trials were increased to 20, dogs were ready for experimental procedures involving IR when 80% or higher for correct rejection rate and hit rate was achieved for two out of three sessions occurring on the same day.

The positive indication (indicating a target) time was initially set to 1000ms to help the dogs learn the target odour and then gradually increased to 4000ms or 4500ms. For a positive indication, the dogs had to hold their nose in the port for 4000ms - 4500ms. Memphis and Bayley had their threshold set at 4000ms for both conditions whilst Ben and Mac had theirs set at 4500ms for both conditions. This was due to Ben and Mac who tended to hold their nose in for longer periods, often leading to false alarms. Bayley and Memphis tended to hold their nose in for shorter periods and found that they would miss targets if the positive indication time was set to 4500ms.

2.13 Design

This study used a within-subject, cross-over design consisting of two condition groups, Simple and Complex. Once the dogs completed the condition they were initially assigned, they switched to the other condition. The dogs were able to experience both experimental conditions at different times, allowing for comparisons to be made. Ben and Mac were assigned to the Complex Condition and Bayley and Memphis were assigned to the Simple Condition. The dogs started on a 100% reinforcement rate and were systematically exposed to a sequence of IR rates. When a dog reached Phase 2 of Phase Change criteria (see Appendix L) they were progressively exposed to lower rates of reinforcement under Simple or Complex target conditions. Once the dogs reached the criteria for finishing the condition (condition termination) they switched to the other condition and continued in the same manner.

2.13.1 Intermittent Reinforcement

IR was introduced once dogs obtained 80% or above for CRR and HR during the experimental procedure. The reinforcement rate initially dropped to 75% and was then reduced by an additional 25% each time the dog met the Reinforcement Change Criteria (see Appendix L). When the dog met Reinforcement Change criteria at 25% reinforcement, the rate was then dropped to 12.5%. Once Reinforcement Change criteria were met at 12.5%, the rate dropped to 6.25%. The reinforcement rate did not go below 6.25%.

2.14 Procedure

2.14.1 Introduction of Chemicals

The dogs started with 12 trials per session for both conditions. Correct rejection rates were observed to ensure the positive indication time thresholds were not made at the expense of accuracy in rejecting non-targets. Once dogs achieved a CRR and HR above 80% for two out of three consecutive sessions, the number of trials was increased to 20, and the ratio of target to non-target was set to 8:12. 20 trials were displayed in a randomised order with one target sample displayed eight times and six non-target samples displayed two times each. There was a total of nine non-target samples, therefore the negative samples included in each session were randomised at the start of every day.

2.14.2 Phase Change Criteria

Phase Change (PC) criteria were established when a dog's CRR and HR were 80% or above for two out of three sessions occurring on the same day. Phase One was when the dogs were at 100% reinforcement rate and PC criteria had not yet been met. Phase Two occurred when PC criteria were met, and dogs were introduced to IR. Each time Reinforcement

Change (RC) criteria were met in Phase Two, the reinforcement rate dropped by 25%, introducing additional non-reinforced targets. Once the dogs successfully progressed through the RC criterion and were at a 25% reinforcement rate, the rate no longer dropped by 25% and instead went from a 25% reinforcement rate to 12.5% and then 6.25%. The rate of reinforcement was not dropped below 6.25%. Once at a 6.25% reinforcement rate, the dogs had to meet RC criteria two additional times at this rate and then were considered to have completed the condition or reached Termination Criteria which was also considered condition completion.

2.14.3 Session Termination Criteria

This occurred when (1) excessive prompting was being used >5 isolated prompts (verbal prompts + gestures). This excluded disruption time by external events (e.g., lawn mowers outside), or (2) a dog discontinued engagement with apparatus in the lab such as not attending to any part that was measurable by the apparatus (lever presses; nose pokes >1min for 2 out of 3 sessions), or (3) the dog spent >1 min in a seated or lying down position not attending to any part that was measurable by the apparatus more than once in a single session.

2.14.4 Phase Termination Criteria

Phase Termination Criteria (PTC) occurred when (1) the dog was not attending to any part that is measurable by the apparatus (lever presses; nose pokes >1min) for two out of three sessions or (2) their CRR or HR was below 40% (<5/12) for two out of three sessions occurring on the same day. Once dogs reached termination criteria they returned to a 100% reinforcement rate. Once PC criteria were reestablished, dogs returned to their last successful reinforcement rate. Once dogs reached RC criteria at their last successful reinforcement rate, they dropped to an intermediary value (i.e. if the last successful reinforcement rate was 75% then it was dropped to 62.5% instead of 50%)

2.14.5 Condition Termination Criteria

Once at a 6.25% reinforcement rate, the dogs had to meet PC criteria two additional times at this rate and then were considered to have finished the condition or reached Termination Criteria which was also considered condition completion.

2.15 Data Analysis

Data was collected both digitally and manually during each session. Sample type, the order in which each sample is displayed, hit rate, and correct rejection rate were collected for each dog in their files. The digital data collected from the custom-designed software interface and stored in the dog's Event File also recorded the amount of time each dog held their nose in the port per trial.

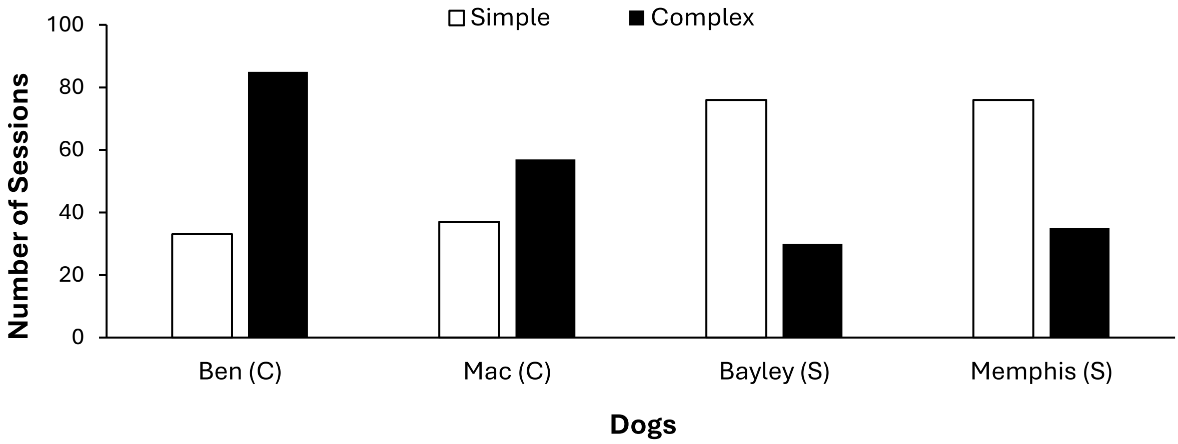
Chapter 3

Results

Figure 5 shows the number of sessions each dog took to complete each condition. Ben and Mac started on the Complex Condition and completed it in 85 and 57 sessions, respectively. Ben and Mac switched to the Simple Condition and completed it in 33 and 37 sessions, respectively. Bayley and Memphis started on the Simple Condition, completing it in 76 Sessions. They then switched to the Complex Condition with Bayley completing the condition in 30 sessions and Memphis completing the condition in 35 sessions.

Figure 5

Number of Sessions Taken to Complete Each Condition



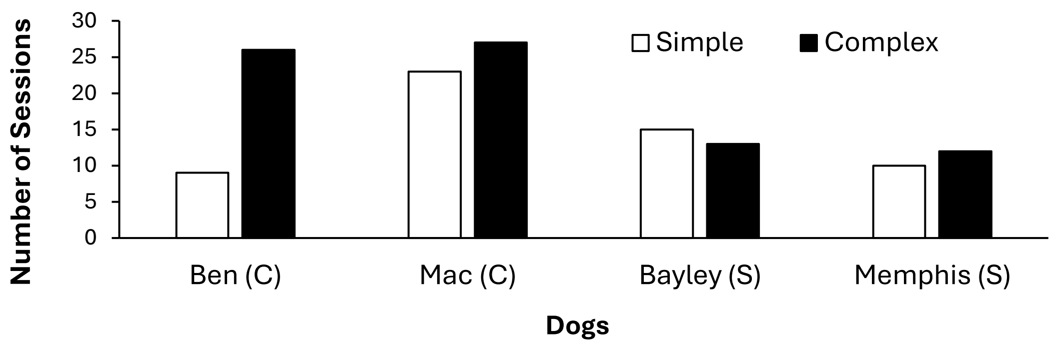
Note: (C) = started on Complex Condition and (S) = started on Simple Condition

Figure 6 shows the time each dog stayed at a 100% reinforcement rate before meeting Phase Change Two criteria to progress to a 75% reinforcement rate. Ben spent 26 sessions on the Complex Condition and 9 for the Simple Condition. Mac spent 27 sessions on the Complex Condition and 23 on the Simple Condition. Bayley spent 13 sessions on the Complex Condition and 15 on the Simple Condition. Memphis spent 12 sessions on the

Complex Condition and 10 on the Simple Condition. Ben, Mac, and Bayley spent less time at the initial acquisition phase on their second condition whereas Memphis spent more time at that initial acquisition phase on the second condition. Ben spent considerably more time in the initial acquisition phase on the first condition he completed (Complex) than his initial acquisition phase on his second condition whereas, Mac, Bayley, and Memphis spent a similar number of sessions at the initial acquisition phase for both conditions.

Figure 6

Time Spent at Phase One/Initial Acquisition

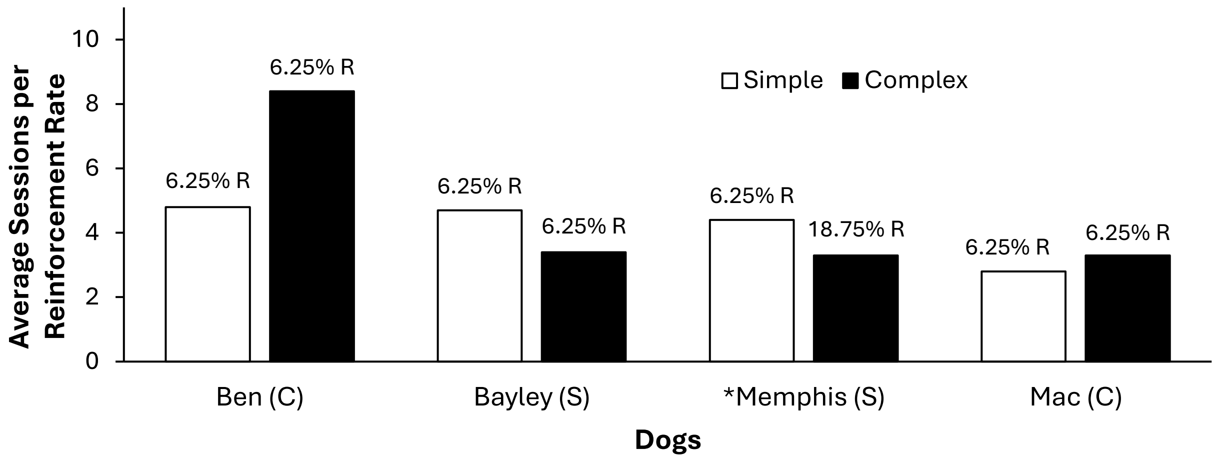


Note: (C) = started on Complex Condition and (S) = started on Simple Condition

Figure 7 shows the average number of sessions each dog spent on each rate of reinforcement excluding their initial acquisition. This includes repeated rates of reinforcement. Ben averaged 8.4 sessions per reinforcement rate for the Complex Condition and 4.8 for the Simple Condition. Mac averaged 3.3 sessions per phase for the Complex Condition and 2.8 for the Simple Condition. Bayley averaged 3.4 sessions per phase for the Complex Condition and 4.7 per phase for the Simple Condition. Memphis* averaged 3.3 sessions per phase for the Complex Condition and 4.4 sessions for the Simple Condition. All four dogs spent less time on average working through each reinforcement rate for their second condition.

Figure 7

Simple vs Complex Condition Comparison Excluding Initial Acquisition



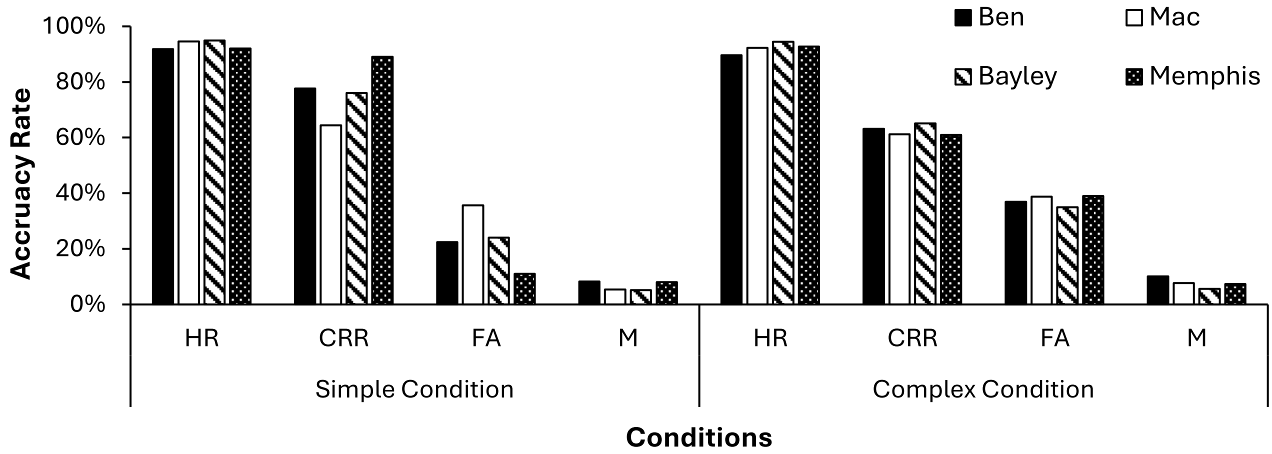
Note: (C) = started on Complex Condition and (S) = started on Simple Condition

* Indicates that Memphis reached condition termination criteria at an 18.75% reinforcement rate whilst the other dogs reached session termination criteria at a 6.25% reinforcement rate.

Figure 8 displays dogs' accuracy rate across conditions. The false alarm (FA) rate was 14.1% lower across the Simple Condition than the Complex Condition (Simple = 23.3%; Complex = 37.4%). The correct rejection rate showed a difference of 14.2% overall (Simple =76.8%; Complex = 62.6%). Hit rate only showed an overall difference of 1% across conditions (simple = 93.3%; complex = 92.3%). Dogs displayed similar results across the Complex Condition than the Simple Condition which showed slightly more varied results between dogs. All dogs displayed a low miss (M) rate across both conditions.

Figure 8

Dogs Accuracy Rate Across Conditions



Note: Hit Rate (HR); Correct Rejection Rate (CRR); False Alarm Rate (FA); Miss Rate (M)

Table 4 displays the dog's average session times for each condition including their initial acquisition. Mac, Bayley, and Memphis spent a similar amount of time on each session, around 7 minutes, whereas Ben averaged around 4 minutes for the Complex Condition. Mac spent on average, 3 minutes less on each session for the Simple Condition than his session time on the Complex Condition whereas, Ben, Bayley, and Memphis averaged similar times for their sessions across both conditions.

Table 4

Dogs' Average Session Times Per Condition

	Minutes	
	Simple Condition	Complex Condition
Ben	4.20	4.86
Mac	4.73	7.79
Bayley	7.03	7.04
Memphis	6.94	7.77

Table 5 shows the number of trials the dogs spent on each rate of reinforcement for the Complex and Simple Conditions. This includes intermediary values. Ben, Mac, and Bayley did not repeat any reinforcement rates on their second condition whereas Memphis repeated the 25% reinforcement rate on his second condition. Ben was the only dog that did not participate in any intermediary values for both condition

Table 5

Number of Sessions Spent on each Rate of Reinforcement for Both Conditions

Dog	Rate of Reinforcement	Condition	
		Simple	Complex
Ben	100%	9	26
	75%	3	3**
	62.5%	-	-
	50%	6	10
	25%	6	5
	18.75%	-	-
	12.5%	3	7
	6.25%	6	3
Mac	100%	23	27
	75%	2	3
	62.5%	-	-
	50%	2	4
	25%	3	2**
	18.75%	-	3
	12.5%	2	4**
	6.25%	5	2
Bayley	100%	15	13
	75%	4**	4
	62.5%	3	-
	50%	3**	2
	25%	3**	3
	18.75%	-	-
	12.5%	2	4
	6.25%	8	4
Memphis*	100%	19	12
	75%	12	3
	62.5%	2	-
	50%	3**	4
	25%	4**	2**
	18.75%	-	2
	12.5%	2	-
	6.25%	5	-

Note: Only initial acquisition sessions were included 100% reinforcement rate and not repeated sessions

* Indicates that Memphis reached an 18.75% reinforcement rate for the Complex Condition whilst the other dogs reached a 6.25% reinforcement rate

** Indicates the number of times a dog took to complete that reinforcement rate on their last repeat of that rate

- Indicates the dog did not participate in that reinforcement rate.

Table 6 shows the number of times each dog went up in reinforcement rate for each condition due to performing poorly enough to meet phase termination criteria. Ben and Mac started on the Complex Condition and went up in reinforcement rate once. Neither Ben nor Mac had to redo any reinforcement rate when they swapped over to the Simple Condition. Bailey started on the Simple Condition and went up in reinforcement rate three times whereas she did not go up in reinforcement rate when she swapped over to the Complex Condition. Memphis started on the Simple Condition and went up in reinforcement rate four times and when he swapped over to the Complex Condition, he went up in reinforcement rate once.

Table 6

Number of Times the Reinforcement Rate was Increased

Dog	Simple	Complex
Ben (C)	0	1
Mac (C)	0	1
Bayley (S)	3	0
Memphis (S)	4	1

Note: (S) indicates the dog started on the Simple Condition and (C) indicates the dog started on the Complex Condition

Log *d* and log *B* were calculated to evaluate dogs' accuracy and bias measures. Log *d* reflects the tendency to respond correctly thus increasing as HR and/or CRR increase and decreasing when a decrease is seen in misses and/or FA (Edwards et al., 2021). Log *B* reflects tendencies or biases towards 'no' or 'yes' responses. Log *B* decreases as 'no' responses increase and increases when 'yes' responses increase irrespective of whether they are correct or incorrect. Table 7 shows that all dogs displayed high Log *d* values, therefore reflecting the tendency to respond correctly across both conditions. Table 8 shows that all dogs displayed positive log *B* values, indicating a bias towards 'yes' responses across both conditions. Memphis displayed a much lower log B value for the Simple Condition. Log *B* and log *d* were calculated to assess the dog's biases and correct responses using the following formula:

log *B* = 0.5 log (HR x FA / M x CRR)

and

log *d* = 0.5 log (HR x CRR / M x FA)

whereas HR is Hit Rate, CRR is Correct Rejection Rate; M is Miss Rate, and FA is False Alarm Rate. Paired-samples *t*-tests were conducted on log *B* and log *d* results in Table 7 and Table 8. The results indicated that there was no significant difference between the log *B* Simple Condition (M = 0.301, SD = 0.179) and Complex Condition (M = 0.432, SD = 0.052; t (3) = -1.451, p = 0.242). Thus, for the Log B results, the null hypothesis was not rejected. There was a significant difference in the scores for log *d* Simple Condition (M = 0.853, SD = 0.103) and Complex Condition (M = 0.656, SD = 0.66; t (3) = 3.945, p = 0.002). Thus, for Log d results, the null hypothesis was rejected.

Table 7

Log d Data Across Both Conditions

Condition	Log *d*			
	Ben	Mac	Bayley	Memphis
Simple Condition	0.794	0.750	0.885	0.984
Complex Condition	0.590	0.638	0.748	0.649

Table 8

Log B Data Across Both Conditions

Condition	Log *B*			
	Ben	Mac	Bayley	Memphis
Simple Condition	0.254	0.493	0.384	0.076
Complex Condition	0.357	0.440	0.478	0.454

Chapter 4

Discussion

This study aimed to determine if odour complexity alters the influence of intermittent reinforcement on dogs' scent detection performance. Ben, Bayley, and Memphis averaged similar times for their session completion across both conditions. Bayley and Memphis started on the Simple Condition and when they switched to the Complex Condition their average session completion time increased slightly. Ben started on the Complex Condition and when he switched to the Simple Condition his average session completion time decreased. This was also evident in Mac's average session completion time however there is a much greater difference in his times as his Simple Condition completion time is three minutes shorter than the complex (4.73; 7.79, respectively). This suggests that the odour complexity for the Complex Condition influenced the dog's performance.

Log *B* values for the Complex Condition are higher than that of the Simple Condition even though the results did not show a significance between scores. However, the values still suggest that dogs had a stronger bias towards indicating a 'yes' response. This may be due to the complexity of the overlapping target and non-target components. Log *d* values for the showed a significance between scores as the Complex Condition is lower than that of the Simple Condition. This suggests that even though the values reflect a tendency to respond correctly, the dogs still have a significantly lower tendency to respond correctly in the Complex Condition. This significance suggests that the complexity of the overlapping target and non-target components impacts dogs' ability to respond correctly.

The dogs completed more sessions on the condition they started on and almost half the number of sessions once they switched to the other condition. Apart from Memphis, all other dogs completed the second condition without needing to repeat a reinforcement rate. No major difference was seen between the initial acquisition times once dogs had changed over to the other condition except for Ben who spent 26 trials on the first condition, and 9 on the second condition. Dogs displayed similar results for correct rejection rate (CRR) in the Complex Condition whereas similar results for hit rate (HR) were displayed across both conditions as seen in Figure 8. Dogs showed a steady increase in CRR during initial acquisition before fluctuating throughout the conditions as seen in Appendix A-H. The dogs' HR accuracy started high during their initial acquisition (see Appendix A-H) and remained reasonably consistent throughout the condition. This also accounts for the increased false alarm (FA) rates that explain the low CRR during the initial acquisition. Overall, dogs displayed higher CRR and FA for the Complex Condition suggesting that over-lapping target components present in the non-target impacts dogs' performance at lower reinforcement rates (25% - 12.5% reinforcement rate).

Dogs were able to progress through reinforcement rates successfully for each condition however a sequence effect, when the results of one condition affect the next condition, appears to be present throughout the above tables and graphs. This likely sequence effect might have obscured the effects of the target complexity. However, results still displayed longer task completion times, lower accuracy in scent detection, and failure to meet performance criteria throughout the Complex Condition.

4.1 Sample Size

The sample size was limited due to only four out of the eight dogs completing the study thus impacting the comparisons across conditions and subjects. Ben had prior experience with carousel training as he participated in previous scent detection research that employed the carousel. Mac did not have prior carousel training however he started shaping behaviour on another project before being placed on this study. Both Memphis and Bayley had no prior shaping or carousel training.

4.2 Limitations

The initial collection of data, phase changes, and reinforcement rate changes was different from the finalised Standard Operating Procedure (SOP) due to changes being made as problems arose in the study. This affected the initial Reinforcement Change (RC) criteria and data collection as it was initially set for dogs to return to the last successful rate of reinforcement. The finalised criterion in the SOP included intermediary values. Another disturbance in the study was Bayley being on heat for her first time. Bayley displayed behaviours of lethargy in the lab room and disinterest in the carousel. This resulted in a visible decline in her results from sessions 35 to 45. As seen in Ben's Complex results from session 25 to 44 there was a major decline in CRR. This decline was speculated due to the chemical mixtures being used for too long of a period. Due to this speculation the timeline for making fresh batches of chemicals/scents was every two weeks.

During the Simple Condition dogs appeared to become familiar with the cues of the carousel moving which resulted in them trying to skip the trial if the carousel had not moved yet even though it was a new trial. After this, two targets and two blanks were used so that the carousel would always move. There were 17 segment places on the carousel thus allowing for there to be two target segments and two non-target (blank) segments for the Simple Condition however this was not able to be held constant in the Complex Condition due to not enough places for the segments. This resulted in the possibility of the same segment being shown twice or more in a row. Another limitation is that the lever is in the path of the food dispenser resulting in dogs occasionally hitting the lever with their tails whilst walking towards the food dispenser and back.

4.3 Future research

Scent detection is used in explosive and landmine detection, medical diagnostics, drug and contraband detection, and many more fields. Scent detection is utilised in many real-life applications highlighting the importance of training on biological targets. It may be helpful to replicate the study with biological or other complex targets to confirm the findings in a 'real-world' task. This can be extended to biological samples that contain a range of organic compounds (VOCs) that might not be able to be replicated using synthetic odours. Researchers can examine the influence of IR whilst training dogs on actual biological and other complex targets such as lung cancer breath samples, explosives, and contraband and compare it with the influence of intermittent reinforcement on the detection of simpler synthetic alternatives.

4.4 Conclusion

Dogs were trained to detect odours under intermittent reinforcement rates in Complex Conditions where the target components overlapped with the non-targets. This study evaluated if odour complexity altered the influence of intermittent reinforcement on dogs' scent detection performance. The results of this study support H1 that an increased odour complexity influenced dogs' scent detection performance under lower rates of reinforcement and H2 that performance was worse in the Complex Condition compared to the Simple Condition under the effects of intermittent reinforcement. This was demonstrated by their longer session times, failure to meet condition termination criteria, higher false alarm rates, and lower correct rejection rates for the Complex Condition. Despite the results of the study, there were limitations regarding sample size, the same segment being presented twice in a row due to limited places, and late changes to the reinforcement rates. To mitigate this, studies can employ a larger sample size and potentially reduce the number of odours presented to limit the number of times the same segment can be displayed in a row.

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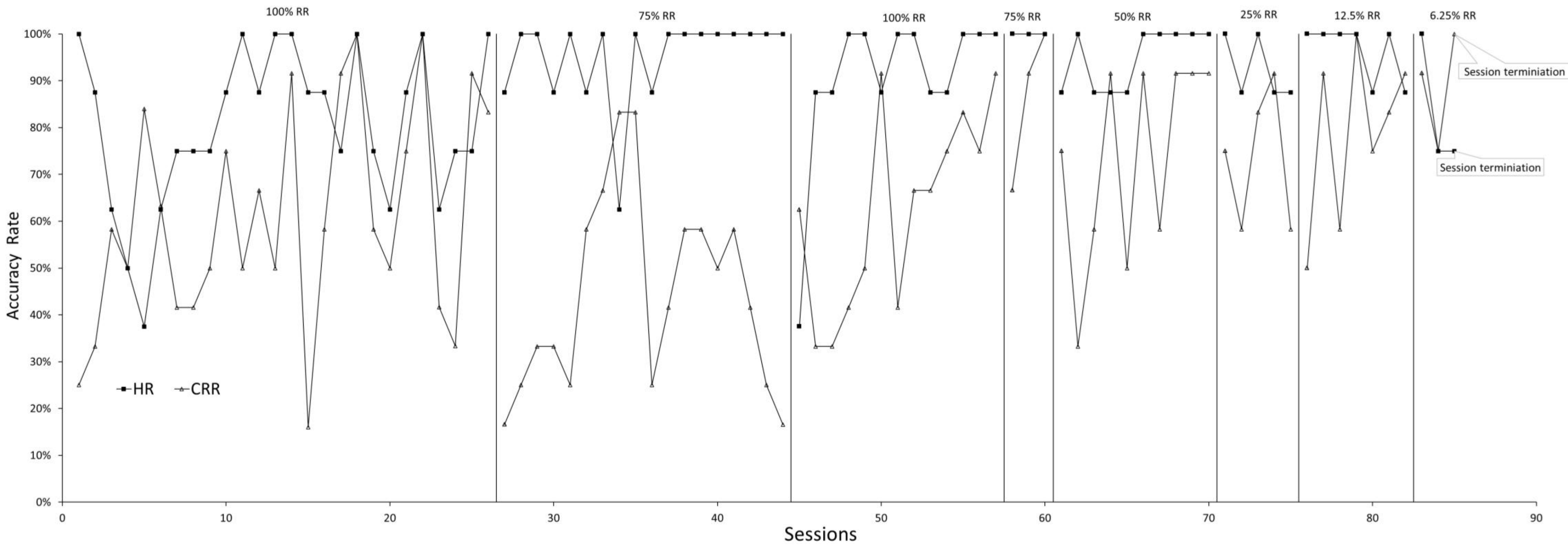
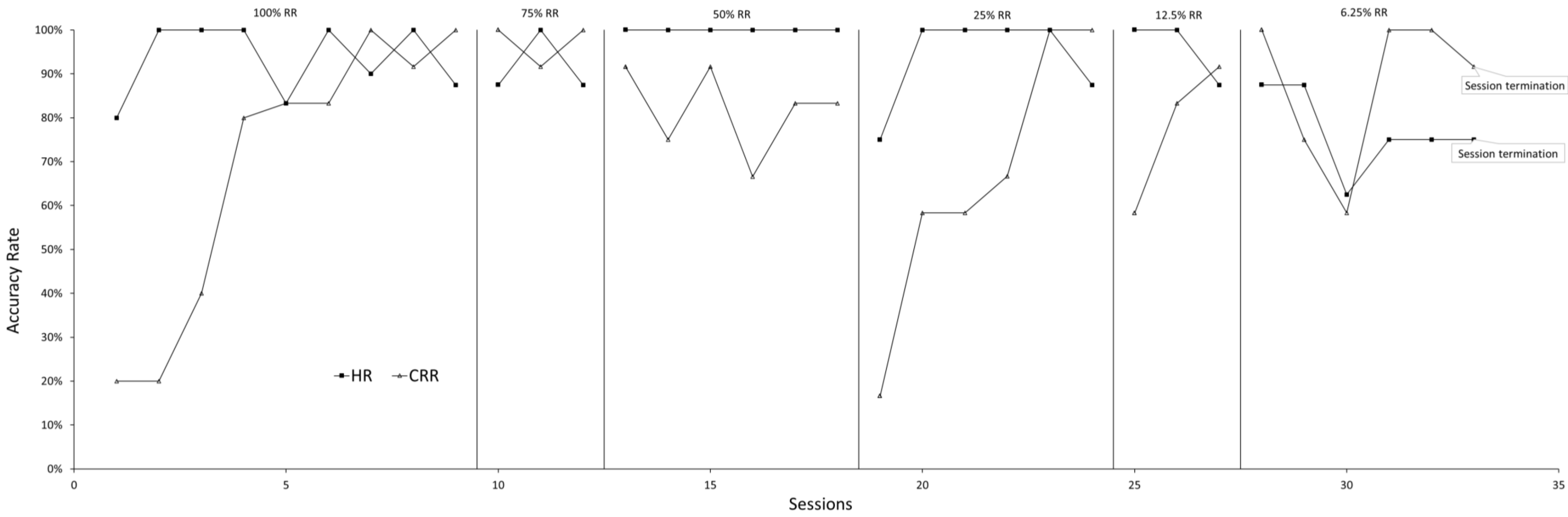
Appendix A

Ben's Complex Condition Accuracy Rate



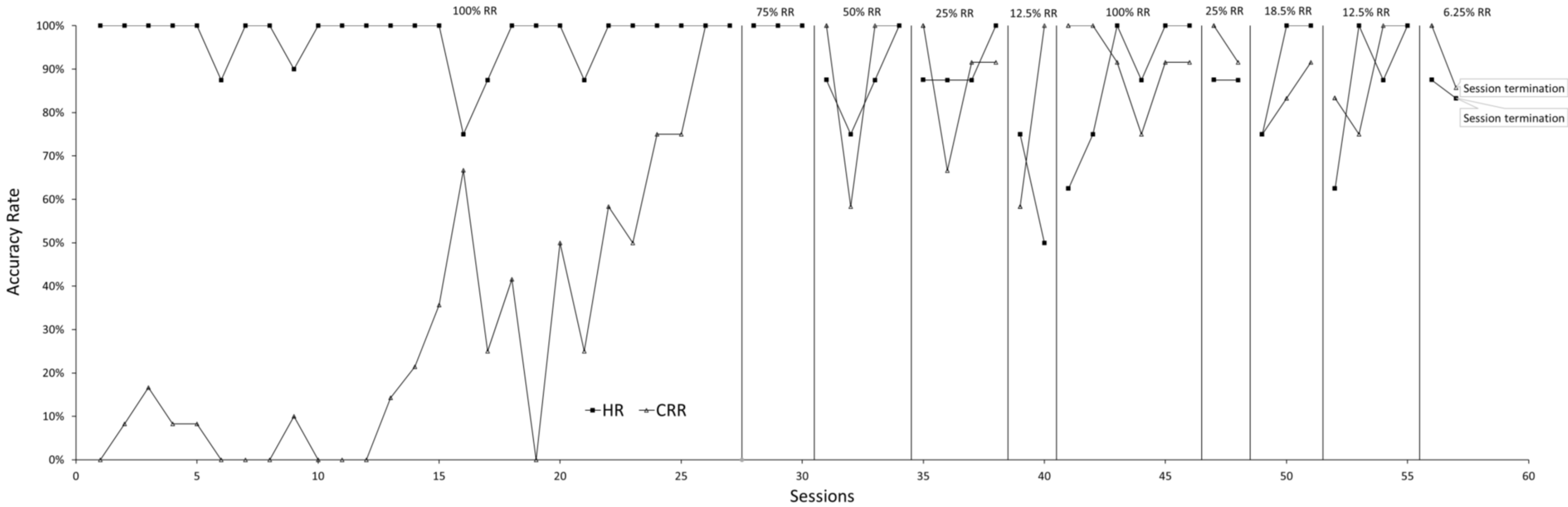
Appendix B

Ben' Simple Condition Accuracy Rate



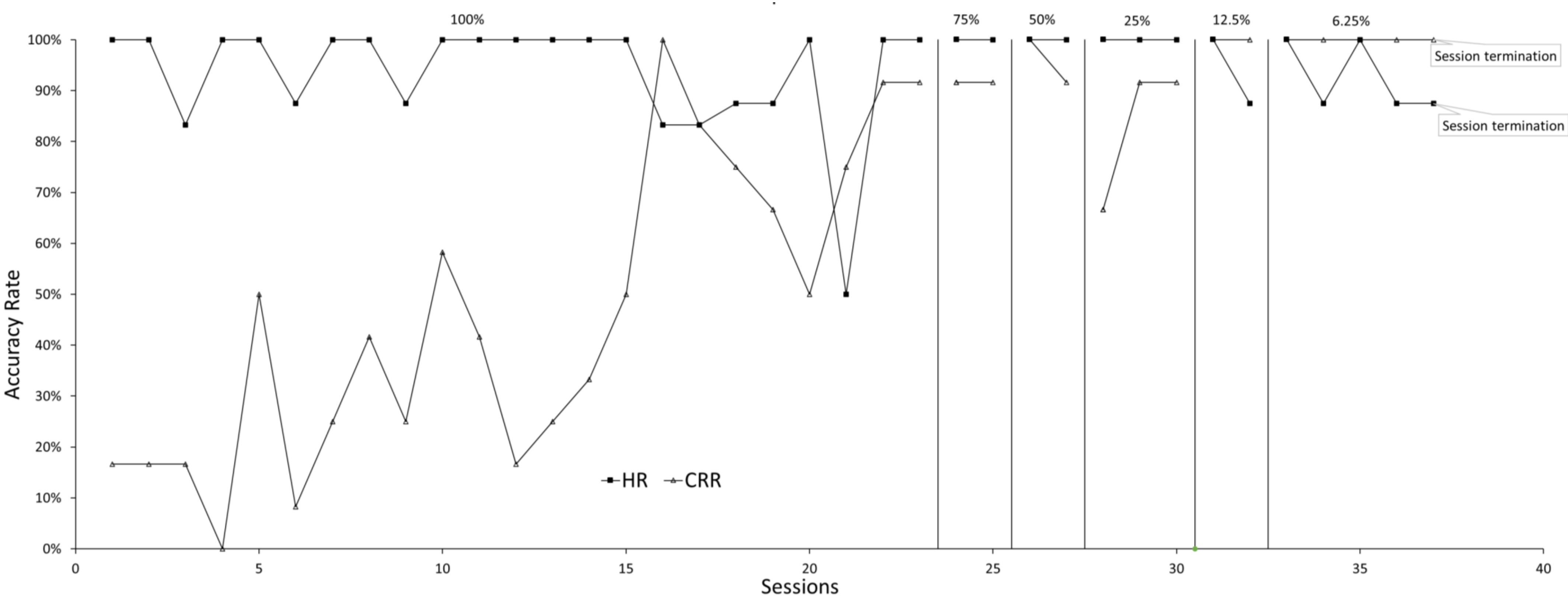
Appendix C

Mac Complex Condition Accuracy Rate



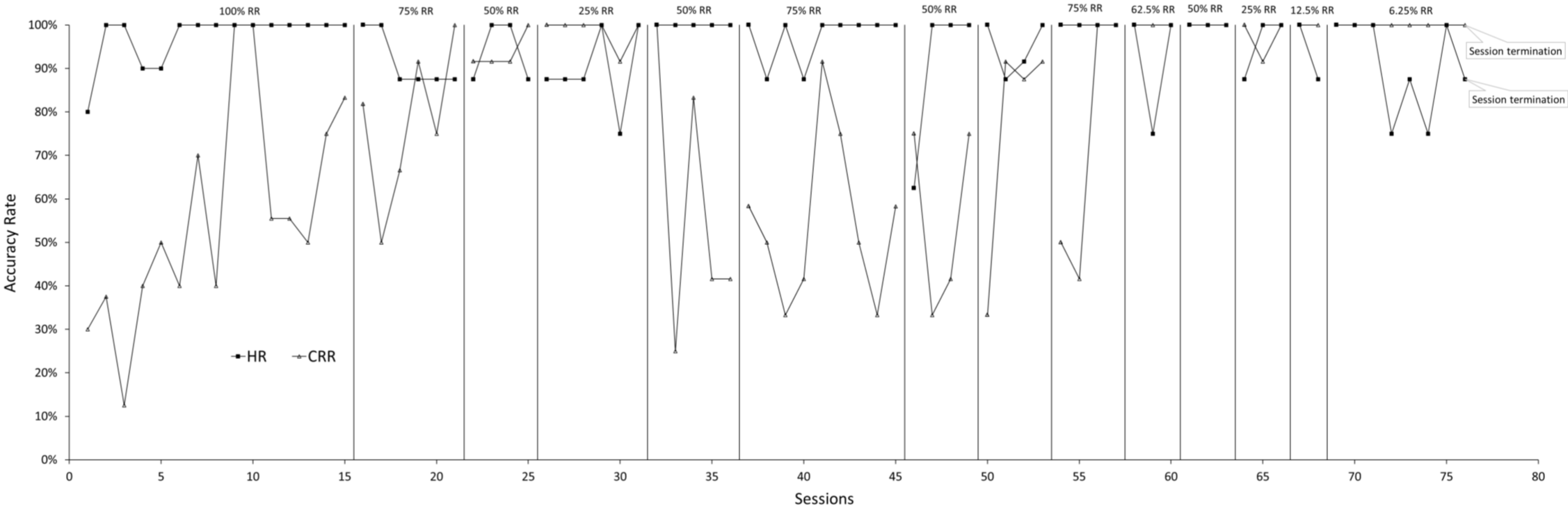
Appendix D

Mac's Simple Condition Accuracy Rate



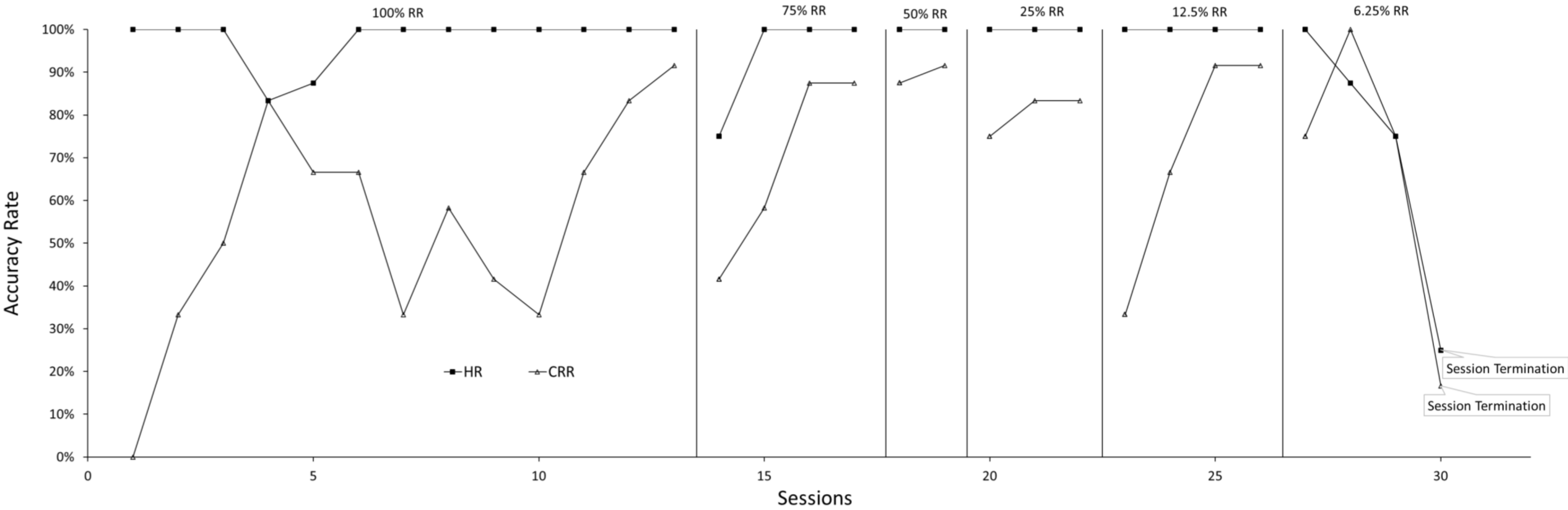
Appendix E

Bailey's Simple Condition Accuracy Rate



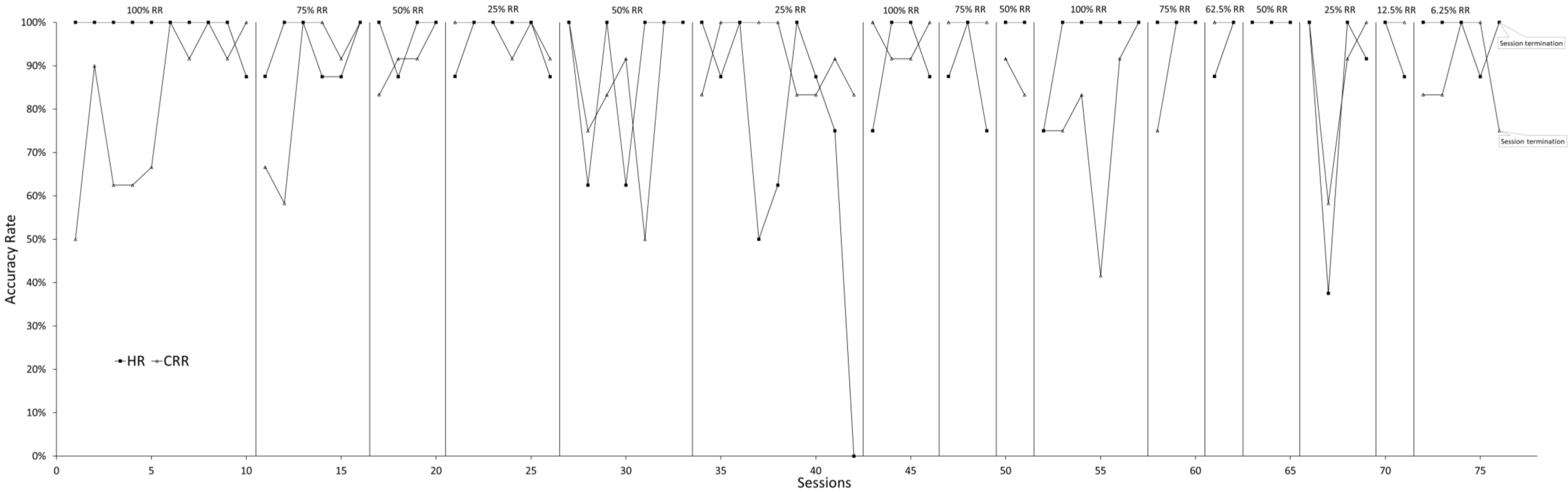
Appendix F

Bayley's Complex Condition Accuracy Rate



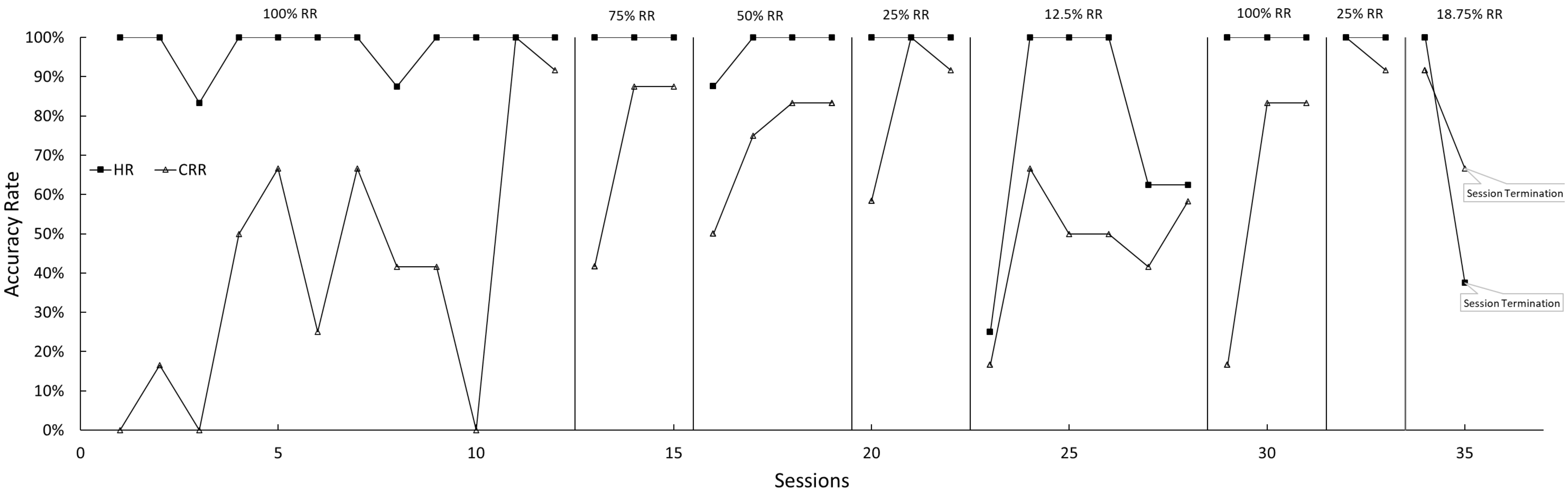
Appendix G

Memphis' Simple Condition Accuracy Rate



Appendix H

Memphis Complex Condition Accuracy Rate



Appendix I

Chemical Sample Preparation SOP

Rule of thumb:

- Always wear a clean pair of gloves before you touch any equipment.
- Only use glassware that has been acid washed.
- Mix the negative sample first to avoid cross contamination.

Equipment you will need before you start (put ready by the hood bench):

1. Purple auto pipette.
2. One yellow tip
3. Two plastic Pasteur pipette (one each for negative and positive samples)
4. 100ml volumetric flask
5. Large beaker
6. Small beaker
7. Two storage jars
8. Two lids
9. Two lid seals.
10. Two pieces of parafilm
11. A paper towel
12. Bucket of water (in case of spillage)
13. Two pairs of gloves

Negative Sample.

Instructions:

1. First, ensure you have clean gloves on.
2. Collect approximately 300ml of deionized water into the large beaker. The deionized water is located on the far right side of the lab, by the fridges.
3. Carefully pour the deionized water into one of the 100ml volumetric flask, not quite up to the line.
4. Use the plastic Pasteur pipette to accurately fill the flask up to the line on the thin part of the flask.
5. Now tip the water from the flask into one of the storage jars.
6. Warm up a piece of parafilm in your hands and place it over the top of the jar.
7. Screw the seal and lid firmly on the jar.
8. Move the jar away from your station to avoid cross contamination and label it appropriately using a vivid.

Positive sample.

1. First, ensure you have clean gloves on.
2. Collect approximately 300ml of deionized water into the large beaker. The deionized water is located on the far right side of the lab, by the fridges.
3. Put the yellow tip onto the purple auto pipette and ensure that it is set to your desired setting.
4. If not, then twist the wheel on the side to adjust it to the appropriate measurement.
5. From the cupboard opposite the acid wash station, get out the amyl acetate container.

6. Place a small amount of the chemical into the small beaker.
7. With the auto pipette, press down on the top button, not all the way and place the yellow tip into the chemical. Realise the button to collect the sample.
8. Place the tip into the volumetric flask and press down on the button all the way.
9. Dispose of the tip onto a paper towel and place the auto pipette out of the way.
10. Take off gloves and put on a fresh pair.
11. Repeat the steps 3-8 of the negative sample instructions.

Appendix J

Sample preparation for carousel use SOP

Samples

Complex Target sample

- Target chemicals: Hexanoic acid, Amyl Acetate, Cinnamaldehyde
- Non-Target: Benzyl acetate

Simple sample

- Target: 1-Otanol
- Non-Target: Blank

Chemical	Chemical Abbreviation	Smell	Vapour Pressure at 25C (mmHg)
	Complex Condition		
Amyl Acetate	A	Banana	5.17
Hexanoic Acid	B	Cheesy/waxy	0.0435
Cinnamaldehyde	C	Cinnamon	0.0289
Benzyl Acetate	X	Jasmin	1.425
	Simple Condition		
1-Octanol	Simple	Rose/Lemony	0.07

Table 2.1

Target and Non-Target compounds and their assigned numbers

Compound	Assigned number
Target Compound	
ABC	1
Non-Target Compounds	
AB	3
AC	4
BC	5
AX	6
BX	7
CX	8
ABX	9
ACX	10
BCX	11

Numbering system

- 1 will always be the reinforced complex target
- 2 will always non reinforced complex target
- 3-11 will be the non-target variations
- 15 will be the reinforced simple target
- 16 will be the non-target blank

Start date

- Wednesday 27|03|2024 complex and simple sample scent detection shaping commenced.
- Non-target variations were gradually rotated until dogs were exposure to all non-targets. This can be done by replacing x number of non-targets for others.
- Combinations are numbered from 3-11 as shown above.

Sample preparation in chemical laboratory

Before the chemistry lab

- Make spreadsheet for randomization of combination rotations for every 2nd-3rd week
- Have 6 non-target combinations for complex
- Have 1 target combination for complex
- Have 1 target for simple

In the lab

- Follow steps on Chemical SOP guidelines for sample prep, handling, and acid washing, and correct PPE

Simple sample preparation

- Get a Schott bottle and glass beaker for the Simple sample which will be prepared first.
- Place under hood bench and fetch 1-Octanol from the cupboard.
- Pour 50ml of deionised water into Schott bottle
- Use yellow tip pipette to get 30**µ**l of 1-Octanol and put into Schott bottle
- Put another 50ml of deionised water into Schott bottle

- Place glad wrap over bottle and seal with lid

Complex sample preparation

- Prepare target sample first
- Get 1 target chemical out of the of the cupboard at a time to avoid using the same chemical twice.
- Pour 25ml of deionised water into required number of Schott bottles
- Get one chemical from the cupboard
- Use yellow tip pipette to get 10µl from the bottle
- Pour chemical into the select Schott bottles
- Pack the chemical back into the cupboard and fetch the next chemical
- Repeat these steps until all samples are finished
- Once finished with the chemicals pour another 25ml of deionised water into the Schott bottles
- Place parafilm over Schott bottle and seal with a lid

Preparation of non-target samples

- Have spreadsheet stating which 6 samples will be used once dog progresses through the current phase.
- Copy steps from the target sample preparation guidelines with the use of the non-target samples as stated on spreadsheet.

05/04/2024: Amendment to usage of non-targets

New non-targets

3. AB

4. AC

8. CX

9. ABX

10. ACX

11. BCX

Complex: 10ml for each

Deionised water: 25ml x 25ml

Appendix K

Basic scent detection acid wash SOP.

Placing into the acid bath:

1. Wear clean latex gloves
2. Tip any unused chemicals into the appropriate waste jar.
3. Rinse all glass wear in the skin.
4. Fill a bucket of water and some paper towels handy in case of spillage.
5. Grab the tongs from the hook by the sink.
6. Put on the long apron located by the acid wash station.
7. Wear long green gloves which are located in the psychology cupboard.
8. Using tongs, carefully place all glass wear into the scent detection acid wash baths. Ensure that all glassware is full, with no air bubbles.
9. Once finished wipe any acid residue with the paper towel.
10. Wash the gloves to ensure any acid is removed from them

Taking out of the acid bath:

1. After the glassware has been soaking in the acid for at least 4 hours, you can take them out.
2. Wearing clean gloves, half fill a bucket with water.

3. Place on the apron and long green gloves.
4. Using the tongs, carefully take out the glassware, emptying as much of the acid when taking it out. Place the items into the half filled bucket.
5. Once all glassware is out, fill the rest of the bucket with water to rinse the glass wear.
6. Empty the bucket and start to rinse the items with demineralised water.
7. Place all items in the oven. If using the small vials, stack them in a large beaker or jar to keep them together.
8. Repeat step 9 and 10 from the previous instructions.

Taking out from the oven.

1. Once your glassware has been in the oven for at least 6 hours you can take it out.
2. Wearing clean gloves and the oven mitt located in the draw under the oven, take out your glassware.
3. Any equipment used to make samples, place a bit of tinfoil over their openings, then place them in their appropriate places.
4. Any sample jars or vials, place in the appropriate container to take back down to the dog lab.

Appendix L

SOP criteria for Phase Change and Termination Criteria

Timelines for dogs switching from one condition to the other will be based on individual performance.

Phase change (PC) criteria:

HR and CRR at 80% or over 2 out of 3 consecutive sessions. All non-targets available due to the possibility of dogs reaching criteria within a day.

Dogs will need to be exposed to all 9 non-target samples

Phase One

Reinforcement rate will be at 100% until all 9 non-targets have been introduced and successfully rejected. There will be no time frame as to how long a dog is to stay on a phase before moving to the next one once they have met phase change criteria.

Phase Two

Introduction of intermittent reinforcement (IR). Reinforcement rate (R) dropped to 75%. This was the same for the dogs on the Simple Condition.

Reinforcement Change Criteria

This occurs in Phase 2 of Phase Change Criteria. Reinforcement Change (RC) Criteria were met when CRR and HR were at 80% or over 2 out of 3 consecutive sessions.

- Reinforcement rate dropped by 25% each time RC criteria were met until termination criteria were reached. Once dogs reached RC criteria at 25% the reinforcement rate was dropped to 12.5% and then 6.25%.

Termination criteria:

Dog is not attending to any part that is measurable by the apparatus (lever presses; nose pokes >1min for 2 out of 3 sessions

OR

CRR or HR has reached below 40% (<5/12) for 2 out of 3 consecutive sessions

Session termination criteria

If excessive prompting is being used > 5 isolated prompts (verbal prompts + gestures)

- Excluding: disruption time (includes but is not limited to; other dogs barking, a person entering the lab, knocking on any of lab doors, lawn mowers outside the lab, food dispenser malfunction, spider/insect crawling across the wall)
- Dog discontinues engagement with apparatus in the lab such as:
    - Dog is not attending to any part that is measurable by the apparatus (lever presses; nose pokes >1min for 2 out of 3 sessions
    - Dog spends >1min in a seated or laying down position not attending to any part that is measurable by the apparatus more than once in a single session.
        - Laying down can be described as the dogs belly touching the floor with both forearms and upper thighs touching the floor.
    - Dog spends >1min in a seated or laying down position not attending to any part that is measurable by the apparatus more than once in a single session and prompted more than once to assist in the continued engagement

Prompts include:

- Walking from one side of the lab room to the other.
- Verbally say ‘here’ with a gesture (pointing with a finger) towards the apparatus
- Verbally come ‘come’
- Tapping the apparatus near the nose port OR on the switch lever

Once termination criteria have been reached

- The reinforcement rate is increased back to 100% until phase change criteria is met again.
- Once phase change criteria has been reestablished the reinforcement rate is dropped back to the last successfully completed phase (i.e. Termination was reached at a 25% R therefore the dog will be placed on a 50% R)
- Once phase change criteria has been met at the last successful phase, the reinforcement rate is dropped down to an intermediary value between the last successful phase and then next phase.
    - An example of this is if termination criteria is reached at 25% R, the rate will be increased to 100% R until PC criteria is reestablished. Once phase change criteria is met the reinforcement rate will be dropped to 50% until phase change criteria is met. Once PC criteria is met the reinforcement rate will be dropped to 37.5% (intermediary value) until PC criteria is met. Once PC criteria is met the reinforcement rate will be dropped to 25%.
- If dogs were on an intermediary rate of reinforcement then either they could reach PC criteria and continue to progress through the phases or if they reached termination

criteria at the intermediary rate of reinforcement then this signaled the end of their participation in that condition.

- Should the dog reach termination and phase change criteria in the same day across 3 consecutive sessions they were kept at the same phase.
- Consecutive sessions are only sessions that occur on a day. If a dog completed sessions 20-22 on one day, then session 23 cannot be considered a consecutive session as it occurred on a new day.

Completion of conditions

Conditions can be completed in two ways:

1. The dog reached the last Phase of the condition which is a 6.25% reinforcement rate. Once dogs reached this rate of reinforcement, they either had to reach termination criteria or they had to reach phase change criteria at that rate of reinforcement two more times.
2. The dog was on an intermediary rate of reinforcement and reached termination criteria instead of phase change criteria thus ending the condition.

Targets vs Non-Target

- The carousel fits up to 17 segments. Segments 1-7 are used for the complex condition and segments 10-13 are used for the simple condition.
- The ratio of targets vs non-targets will be 8:12, respectively
- For the complex condition, 1 target is displayed 8 times and 6 non-targets are displayed 12 times. Each non-target is displayed twice.

- For the simple condition, 2 targets are displayed a total of 8 times and 2 blank segments containing nothing are displayed a total of 12 times. There is no limit to how many out of the 8 times the same target is shown (i.e. segment 10 or 12 is displayed 5 times) as long as segment 10 is not displayed in 2 consecutive trials. This is the same for the blank segments 11 and 13.
- Fresh batches of Targets and Non-Targets are mixed every 2 weeks.

Complex Condition:

- All 9 non-targets (NTs) are to be used in a constant rotation. The NTs will be randomised every lab session unless only 1 or no sessions were conducted in a day.
- 6 out of the 9 NTs will used in every session and each of the 6 NTs will be displayed twice creating 12 non-target trials out of 20

Simple Condition:

- 2 target segments are displayed in a total of 8 out of 20 trials
- 2 blank segments with nothing inside are displayed as non-targets in a total of 12 out of 20 trials

Chemical placement on carousel for simple cohort:

- 4 segments will be placed next to each other (segments 10-13). 2 segments (10 & 12) will contain the target and the other 2 segments (11 & 13) will be blank. They are placed in the following sequence: target (10); blank (11); target (12); blank (13).
- Once the trials are randomised and two or more targets are displayed consecutively then the carousel will be programmed 10;12;10 to stop the same segment being shown twice in a row.

- This is so the carousel does not stay in the same position. This is to avoid the dogs learning that the carousel has stayed at the same segment as the cue the carousel makes when turning is not given.