Investigating Canine Colour Preference Through a Free Choice Preference Test

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Abstract

Dogs are one of the most common pets worldwide, and promoting their welfare is a key concern for many owners. Numerous studies have been performed investigating dogs' cognitive and sensory capabilities, from which we know that they have poorer vision than humans, including dichromatic vision and red–green colour blindness. Instead, they rely heavily on their other sensory modalities, such as olfaction and low-light detection. Little research has investigated whether dogs show preferences for less dominant sensory cues, such as colour vision, and how this may be integrated into their environment to enhance welfare.

This study aimed to investigate whether dogs display a colour preference when presented with three different coloured stimuli in a free-choice preference test based on their visual spectrum. Sixteen domestic dogs were included in this study. Of these, two were used in the pilot study, one was excluded due to a lack of habituation prior to testing, and thirteen were included in the main study. Three coloured bowls containing food (red, blue, and yellow) were presented simultaneously in fixed locations (left, middle, right) over three testing days and a total of 18 trials. Behaviours measured included first bowl visited, number of visits, duration of visits, percentage of time spent interacting with each bowl, latency to approach each bowl, and the first bowl visited in each trial. Data were analysed using either chi-square tests, Fisher's exact tests, ANOVA, or Poisson regression, with dogs as either a repeated measure or fixed effect, to assess both individual and population preferences.

No significant effect of colour was observed at either the population or individual level. Some individuals showed a tendency to prefer red, and overall, dogs approached the red bowl faster than others. However, there was a strong preference for the right-sided location at both the individual and population levels. This location preference became more prominent over repeated trials, possibly overriding any potential colour preferences.

The presence of some weak individual colour preferences indicates that colour may play a role in decision-making for some dogs, warranting further research, including more trials and a larger sample size. These findings highlight that while dogs are capable of discriminating colours, it may not be a primary driver of canine choice behaviour. Understanding these patterns has practical implications for promoting canine welfare. Colour alone may not be useful to enhance

welfare, but it may still be incorporated alongside other sensory features to support positive experiences.

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1. Literature review

1.1 Dogs as Companion Animals

Dogs (*Canis lupus familiaris*) are among the most popular household pets globally (Hepper & Wells, 1997; Slater et al., 2008). A 2016 survey showed that over half the world's population owned a pet, and dogs made up one-third of these household companions (Knowledge, 2016). In a New Zealand survey on pet ownership, 63% of households reported owning a companion animal, and 31% reported owning a dog, with an estimated 830,000 dogs kept as companions in NZ (Forrest et al., 2023). It was reported that 33% of Australian, 50% of US, and 66% of Argentine households had a pet dog (Knowledge, 2016). There are clear variations between the populations of dog owners in different countries, such as double the number of households in Argentina owning dogs compared to New Zealand. The population of dog owners is increasing, with a 113% increase in dog owners in China between 2014 and 2019 (Dan et al., 2024), and dog ownership in the USA increasing by 12 million dogs from 2016 to 2020 (Larkin & Radich, 2021). Trends are rising globally, influenced by demographic changes, with younger generations choosing to have 'fur babies' rather than biological children, and in some countries, the number of dog owners has surpassed the number of households with children (Kubinyi, 2025).

Dogs are considered by many to be part of the family (Albert & Bulcroft, 1987; Kubinyi, 2025). A large percentage of owners refer to their dogs as family members, celebrating their birthdays, and experiencing the same severity of grief for the loss of their dog as they would for the loss of a human (Archer, 1997). People also reported forming stronger attachments to their dogs compared to other kinds of pets, viewing them as an important source of comfort and part of their lives (Archer, 1997).

A key reason for the popularity of dogs in Western countries is that owners associate having pets with increased positive experiences. Numerous studies have demonstrated that having a dog positively impacts both physical and mental health in humans (Dan et al., 2024; Powell et al., 2018; Rathish et al., 2022). A survey analysing the benefits and challenges of dog ownership reported that 89% of people experienced happiness, 74% decreased stress, and 61% decreased loneliness (Powell et al., 2018). People who had previously or currently owned a dog also reported more positive

experiences associated with dog ownership than non-owners. There are also strong associations between dog ownership and increased levels of physical activity, which plays a significant role in reducing symptoms of depression and anxiety (Clark Cline, 2010). These physiological benefits are attributable to the active lifestyle linked to caring for a dog, particularly their walk and interactive play requirements. Engaging in even 30 minutes of moderate physical activity per day, commonly achieved through dog walking, has been found to significantly enhance both psychological and physical well-being (aan het Rot et al., 2009).

People who own pets are also perceived as being more friendly and easier to approach, which can lead to increased opportunities for social engagement. This can help owners to form more social networks through their dogs, such as with trainers, breeders or other animal lovers and owners (Sussman, 1985). Additionally, research has shown that children raised with dogs exhibited higher levels of empathy and nurturing behaviour compared to those who grow up without pets (Walsh, 2009). One study indicated that adults who were divorced, widowed, or childless formed stronger attachments to their pets (Albert & Bulcroft, 1987).

The appeal of puppies and certain dog breeds may stem from their neotenous (juvenile) features, which trigger a caregiving response similar to that of a parent with a child. These features help create a strong emotional bond between humans and dogs. In some cases, dogs are anthropomorphised to the extent that they are used as a surrogate in place of human contact, and owners have been known to enjoy the company of their dog more than people (Sussman, 1985). Many people consider them as a reliable companion whom they can trust and who would never betray them (Dotson & Hyatt, 2008). The idea of their unconditional love makes them a popular companion, particularly with people who do not have other dependents, so they idolise the idea of complete love and devotion that having a dog brings (Perin, 1981). While dog ownership offers numerous benefits to humans, it is important to recognise that the welfare of dogs is equally dependent on the quality of care, environment, and management practices provided by their owners.

1.2 Animal Welfare

Many dog owners strive to provide positive experiences and improve their pets' welfare due to strong emotional attachments and a tendency to view their dogs as surrogate children (Lustig & Cramer, 2015). Positive experiences through good dogmanship have also been linked to improved training outcomes and encourage better canine behaviour, thus strengthening the bond between dog and owner, and increasing positive interactions for both (Payne et al., 2015).

Animal welfare can be characterised as an animal's affective state, referring to the subjective range of emotions and feelings animals experience, which arise from perceptions of their internal physiology and external environmental conditions (Hall & Kay, 2024). Animal welfare focuses on more than just the physical state of an animal, and emphasises that sentient animals can experience positive and negative emotional states such as pleasure, comfort, curiosity, pain, and fear (Guesgen & Bench, 2017). Affective states often drive goal-directed behaviours such as exploration, foraging, and socialisation (Mellor, 2015).

Since an animal's affective state cannot be directly measured, welfare assessments rely on evidence-based approaches that interpret behavioural and physiological indicators to infer mental experiences (Mellor, 2016). We can observe goal-directed behaviours and patterns of interaction to infer how an animal is feeling and identify ways to enhance its welfare (Hemsworth et al., 2015). An animal's welfare state can be assessed using the Five Domains Model (Mellor et al., 2020). This framework consists of five main focuses: nutrition, environment, health, behavioural interactions, and mental state (Fig.1). The first three domains (nutrition, environment, and health) are primarily focused on the animals' internal functional states. These encompass their basic biological needs relating to their general health and functioning (Fraser, 2008). The fourth domain (behavioural interactions) focuses on their external circumstances, encompassing social and environmental interactions (Mellor et al., 2020). Domain four focuses on opportunities for animals to exercise 'agency', which is their ability to engage in voluntary, goal-directed behaviour, and make their own choices (Špinka, 2019). The first four domains are used to collate evidence, which is then used to infer mental experiences in Domain 5. The animal's overall welfare status is based on the integration of all their positive and negative experiences at a given point in time.

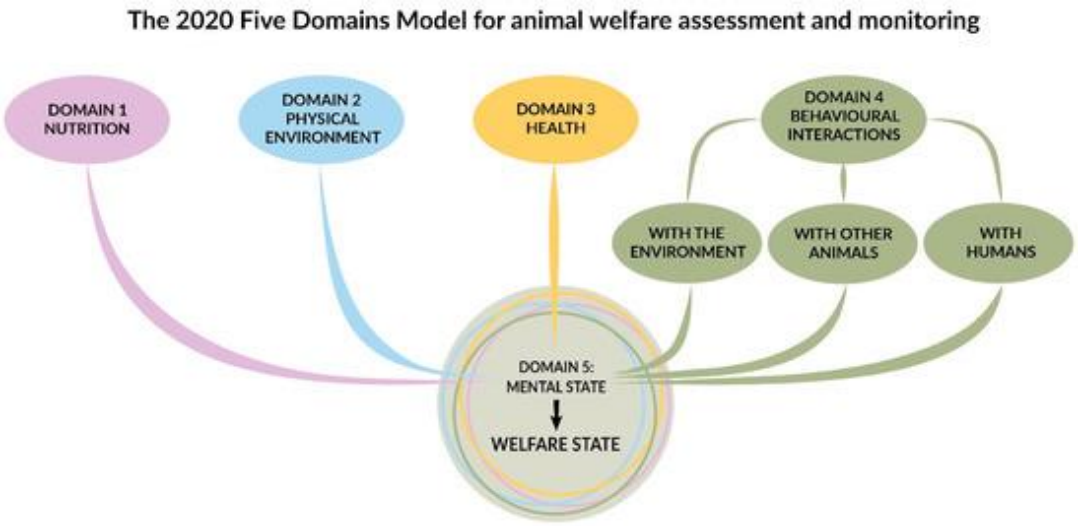

Figure 1. The 2020 Five Domains Model, illustrating how the biologically focused domains, nutrition, environment, and health, along with behavioural interactions, contribute to the animal's mental state. Domain 5 reflects the cumulative affective experiences arising from the first four domains and determines the overall welfare status. Illustrated by Wilkins et al. (2024).

The Five Domains Model of animal welfare emphasises that ensuring good welfare involves more than just preventing suffering and eliminating negative experiences; it also requires actively enhancing the animal's quality of life by promoting positive experiences, for example, by providing an engaging environment and opportunities to express highly motivated behaviours (Mellor et al., 2020). The understanding of good welfare has moved beyond just the focus of minimising harm and instead recognises that animals are capable of experiencing a wide range of positive emotions, including pleasure, curiosity, confidence, and social bonding. When the first four domains, nutrition, environment, health, and behavioural interactions, are managed in ways that go beyond basic needs and instead offer opportunities for engagement, animals can experience a richer and more fulfilling life. For example, providing variable and palatable feed can stimulate interest and enhance sensory pleasure. Access to comfortable and species-appropriate shelter can promote feelings of security and restfulness, and opportunities to explore, forage, and perform natural behaviours can lead to positive engagement such as social bonding, play, and improved human–animal interactions (Table 1). These experiences contribute to the overall mental state of the animal, which is expressed in Domain 5 (Mellor, 2017). When

animals are given appropriate opportunities, this can promote positive experiences and enhance welfare, allowing the animal to thrive rather than simply survive.

Table 1. Examples of positive and negative conditions across the first four domains of the Five Domains model, and their associated positive and negative affective states in Domain five adapted from Kells (2022).

Domain	Negative Conditions (Domains 1–4)	Negative Affective States (Domain 5)	Positive Conditions (Domains 1–4)	Positive Affective States (Domain 5)
1. Nutrition	Prolonged Hunger or Thirst, Poor- Quality or Unpalatable Diet, Forced Feeding or Food Restriction	Frustration, Discomfort, Distress, Thirst, Hunger, Lethargy, Boredom	Access to Clean Water, Varied Palatable and Sufficient Diet, Voluntary Feeding	Satisfaction, Comfort, Pleasure
2. Physical Environment	Overcrowding, Exposure to Harsh Temperature, Loud Surroundings, Lack of Resting Area	Anxiety, Helplessness, Irritability, Depression, Fatigue	Thermal Comfort, Shelter, Quiet Stable Environment, Soft Bedding, Ample Space to Rest and Move	Relaxation, Security, Calmness , Relief
3. Health	Acute or Chronic Pain, Illness or Disease, Injury, Fatigue	Suffering, Depression, Lethargy, Malaise	Absence of Pain and Disease, Regular Medical Care, Physical Fitness, Recovery from Illness	Vitality, Relief, Physical Ease, Energy
4. Behavioural Interactions	Inability to Express Natural Behaviours, Social Isolation, Lack of Stimulation, Forced Handling, Barren Environment	Frustration, Boredom, Loneliness, Fear, Anxiety, Depression	Social Contact, Freedom to Explore and Play, Control Over Actions, Positive Human-Animal Interaction	Curiosity, Joy, Affection, Engagement, Confidence, Pleasure, Energised, Excitement

Most owners want to provide the best possible care for their dogs, as they would for a family member. In a survey of adults' perceptions on the importance of dog welfare, 95% of the respondents agreed that the overall welfare of dogs is very important (Cobb et al., 2020). Another survey of dog owners found that most participants strongly believed they had a duty of care and a responsibility to ensure their dog's happiness and health (Glanville et al., 2023). Despite these positive intentions, the reported levels of welfare did not consistently align with these beliefs, and many owners acknowledged they could do more to improve their dogs'

welfare. These differences are likely due to a lack of awareness and understanding of how their own behaviour and interactions impact their dog's welfare. While most owners recognise that dogs need opportunities to play and express natural behaviours such as chasing, chewing, and barking (Morris, 2016), many lack the knowledge to provide these experiences in an engaging and safe way.

1.2.1 Agency Can Improve Welfare

One way to support positive dog welfare is by providing dogs with opportunities to make choices, allowing them to engage in voluntary behaviours and express agency (Špinka, 2019). Agency arises from biological instincts and cognitive motivation; it is related to welfare (particularly Domain 4 of the Five Domains model (Fig.1)) because it enables animals to interact meaningfully with their surroundings and is closely linked to engagement. Engagement refers to the animal's active involvement with its environment, tasks, or challenges, typically requiring cognitive effort, attention, and motivation (Browning & Veit, 2025). While owners can create opportunities for agency, such as offering multiple choices, puzzles, or interactive environments, agency itself is expressed by the individual animal. It is not something we can directly give, but it can be enabled through the opportunities we provide. Thus, supporting agency involves more than providing animals with toys or objects; it means structuring environments to allow them to express preferred behaviours and participate actively in shaping their experiences, promoting welfare through more enriching experiences (Littlewood et al., 2023).

The value of agency can be distinguished more clearly when considering its evolutionary background. In the wild, animals must solve problems to adapt and survive, such as finding food, avoiding predators, and withstanding harsh environmental pressures (Špinka, 2019). While these survival conditions can negatively impact welfare, natural selection has shaped animals' physical and cognitive abilities to cope with and adapt to these challenges. Research suggests that the evolution of intelligence in carnivores can be linked to the innovation to solve more complex challenges and adapt to changing environments (Holekamp & Benson-Amram, 2017). Although domesticated animals are no longer under the same survival challenges, they have retained the genetic predispositions, motivation and cognitive abilities to engage in problem-solving behaviours that have been inherited through their evolutionary history. When animals that are

kept as pets are not given the opportunities to express these behaviours, their agency is restricted, thus negatively impacting their welfare in the behavioural Domain 4 (Fig.1).

Without adequate opportunities to engage in cognitive and behaviourally challenging tasks, such as those reflected in Domain 4, animals may experience boredom, frustration or anxiety (Table.1). Many studies have suggested that animals benefit from having control over their environment, with one study even finding that animals in barren environment would rather seek aversive stimuli than be in a state of boredom (Burn, 2017). This emphasises the importance of agency for animals and supports the benefits of providing choice and cognitive challenges.

1.2.2 How Owners Can Provide Agency

The ability to express agency is closely linked to positive emotional experiences and improved overall welfare in animals (Meehan & Mench, 2007). Owners can help support agency in their animals primarily through the provision of enrichment.

Enrichment involves creating environments that provide stimulating choices and cognitive challenges, encouraging natural species-specific behaviours and enhancing welfare (Young, 2003). It improves both mental and physical well-being by promoting engagement and interactions, particularly for animals in captivity who lack the environmental challenges of their wild counterparts. There are different types of enrichment strategies that can be used, including; physical tools (climbing structures, objects to move, chew, chase or forage), social tools (intra and inter- species interactions), cognitive tools (solving tasks, working to obtain a reward), and sensory (olfactory, tactile, auditory, taste, or visual) (Veissier et al., 2024). Various enrichment tools have been applied across a wide range of species and settings, including for laboratory and farm animals, to reduce boredom-related behaviours such as aggression and stereotypies (meaningless repetitive behaviour such as pacing, excessive grooming, or head bobbing), and for zoo or companion animals to enhance human–animal interactions (Kresnye et al., 2022). Providing appropriate enrichment promotes agency by adding complexity to an animal's environment, offering meaningful choices, and encouraging goal-directed behaviours that reflect their natural instincts.

Agency can be promoted through toys and problem-solving challenges that require effort to obtain the reward, encouraging play behaviour and cognitive enrichment (Wells, 2004b). Additionally, enrichment tools can be useful for enhancing human-animal interactions by using toys that require human involvement, such as playing fetch, which can create more positive associations and strengthen the bond with their owner. A common form of enrichment is food-based. For example, zoos commonly present the animals' usual food in a more challenging way, such as feeding bears live fish they have to catch as they would in the wild, or placing food up high in trees to promote climbing (Wagman et al., 2018). For companion animals, puzzle bowls, lick mats, and slow feeders are all useful products that require the animals to work harder for their food and provide mental stimulation (Schipper et al., 2008). By using a variety of high-value foods, these tools can enhance their sensory experiences and encourage them to work harder for it. If the reward offered is not something that holds much value to them, animals are less likely to engage and want to work for it. It is also important to change and offer new challenges; otherwise, they lose their mental complexity and become just a physical barrier (Meehan & Mench, 2007). For example, if a dog is given the same feed puzzle every night, they will remember how to solve it quickly from their previous experience, and it will no longer be challenging for them, but just something they must do to get the food. Although it is still stimulating as it requires work, it has less enrichment value than the complexity required to first solve it (Meehan & Mench, 2007).

Providing a variety of valuable toys and other forms of enrichment allows animals to make choices based on their individual preferences, giving them greater opportunities for decision-making. Research investigating the influence of different toys on dog behaviour found that when presented with multiple options, dogs interacted with each toy differently, in terms of duration and type of interaction (Wells, 2004a). While all toys stimulated play behaviour and physical activity, some were significantly more effective in maintaining interest compared to others. These findings also indicated that individual dogs had different preferences, and offering a variety of enrichment objects allowed them to express and explore their individual preference. Moreover, providing multiple types of stimuli can help reduce the likelihood of habituation and boredom, which often occur when animals are given limited choices (Meehan & Mench, 2007). Assessing preference by observing an animal's choices and behaviours offers valuable insight

into their specific needs and how we can use this to tailor enrichment tools to improve their welfare (Puls et al., 2024).

1.2.3 Providing Opportunities to Express Preferences and Choice Improves Welfare

If given the ability to choose, individuals may express their preferences for various stimuli or factors relating to these, such as smell, texture, size or colour. By providing animals with the opportunity to behave and interact with numerous stimuli, it helps us to identify what types of enrichment are most meaningful and promote their ability to express specific behaviours (Meehan & Mench, 2007).

The welfare of dogs is influenced by the opportunities that owners provide. Without access to a variety of options, dogs may be unable to express agency, thereby leading to boredom, anxiety and other negative states of welfare due to the inability to express their natural or preferred behaviours (Table 1). To support good welfare, it is essential to offer conditions or objects aligned with individual preferences. This requires assessing and responding to each dog's unique interests. If dogs are not given the chance to express personal preferences and engage meaningfully with their environment, their overall quality of life may be negatively affected. If a dog is also given choices but doesn't enjoy any of the options available, it may not truly perceive genuine agency in their decisions. Thus, it is important to understand what rewards they are driven to work towards based on their preference, so they may perceive genuine agency, showing voluntary behaviours and associate their training with positive experiences.

1.3 Animal Preference Testing

Preference can be defined as "The action of or an act of preferring or being preferred; a greater liking for one alternative over another or others" (Anonymous, 2025). It is a key cognitive function that impacts decision-making and the capacity to assign value to things (Slovic, 1995). For something to be defined as a preference, it is assumed that 'a' will always be chosen over 'b', and there will be a consistent pattern of favouritism (Sen, 1973). Identifying a pattern of preference, particularly within a population, is valuable for animal welfare. If the majority of individuals within a population repeatedly favour one option over others, this suggests it better

meets their needs (Kirkden & Pajor, 2006), and these findings can be used to guide welfare improvements and husbandry practices.

Preference is a critical component of goal-directed behaviour and may be subject to change over time. For example, when an individual is presented with the option of food or water, their selection may vary depending on whether their current goal is to alleviate hunger or thirst (Warren et al., 2011). When assessing preference in animals, which cannot directly tell us how they are feeling, this can be very useful to determine what they require to improve their mental state. For instance, to enhance welfare through environmental changes, we might offer indoor vs. outdoor housing. If an animal consistently chooses indoor housing, it may indicate discomfort outdoors due to the cold, harsh substrates, or other factors. The preference to move inside is driven by their goal-directed behaviour to avoid these things, and highlights specific areas for improvement, supporting better welfare through the environmental domain of the Five Domains Model (Fig.1).

Animal preferences are understood through their choice behaviour, which refers to their process of decision making and selection of a particular choice when given multiple options (Hausman, 2011). Many animals develop a preference through learning and experiences, leading to positive or negative associations (Protti-Sánchez et al., 2023). Thus, personal experiences may lead to animals seeking or actively avoiding certain environments or objects based on their individual preferences.

Preference reflects a difference between motivation to obtain or avoid a stimulus or reward (Kirkden & Pajor, 2006). Motivation is an animal's strength and willingness to engage in a particular activity and is thought to be driven by operational processes within the brain that control physiological changes and behaviours (Toates, 1986). In animal science, motivation is commonly assessed to determine how strongly an animal values a resource or reward by linking their behavioural response to a measurable outcome (Kirkden & Pajor, 2006). Another recognised drive for motivation is emotion. Findings have shown that an animal will perform goal-directed behaviours to alleviate a stressful situation, such as being driven to find water due to feelings of thirst (Toates, 1987). Both operational and feeling-directed motivation can be used

to study preference in animals, as their willingness to engage can also be linked to how the animal is feeling and is shown through their actions.

1.4 Preference Testing Methods

Preference tests can help us understand how an animal is thinking without verbal communication (Baxter et al., 1983); instead, they show preference through their interactions and choices. Methods of testing revolve around animal-centred information. There are different types of preference testing that can be used to study different reactions in a variety of animal species. Multiple types of testing methods can also be used together to study the variability and strength of preference when the way objects are presented, or other variables are changed.

Despite the variation between methodologies, all preference tests have the same goal: to identify if animals consistently favour one choice more than others, or to what extent they are driven to avoid certain stimuli (Fraser & Matthews, 1997). When conducting preference tests, it is important to consider the limitations and strengths of each to be able to confidently confirm if there is a true preference for individuals or within the population (Kirkden & Pajor, 2006).

1.4.1 Single Stimulus Choice Method (Successive Choice)

Presenting a series of stimuli one at a time to an individual and observing their reaction can show their preference for certain stimuli based on their emotional responses. Single stimulus methods are a technique commonly used to understand the engagement and enjoyment of different stimuli in humans with behavioural or learning deficits (Pace et al., 1985). By presenting one stimulus at a time, the participant's emotional reaction to the stimulus can be directly observed to see if they have an aversive or positive response towards it (Hagopian et al., 2004). This approach is less commonly used in animal preference testing because it relies on interpreting emotional responses, which are susceptible to observer bias due to subjective interpretation of body language. Additionally, presenting only one stimulus at a time reveals approach or avoidance behaviour, but does not provide information about the relative ranking or hierarchy of preferences among multiple stimuli. Compared to other testing methods, single stimulus presentation has been shown to be less accurate and consistent than other methods (such as

paired stimulus and multiple stimulus assessments) in human studies (Kang et al., 2013). Therefore, this method would not be useful for studying colour preference in dogs.

1.4.2 Multiple Stimuli/Choices

Fixed Choice Preference Tests

Fixed choice preference tests generally use a maze construct where access to stimuli is limited so the subject can only go to or see one stimulus at a time based on their choice of pathway (d'Isa et al., 2021). Prior training is done with the animals, so they are aware of the stimulus at the end of each path. Fixed choice preference tests are often used to study the effects of the environment, such as preferred housing areas or floor substrates (Browne et al., 2011). They are also used to examine anxiety-like behaviours in individual subjects, which can then be used to improve their welfare if they show clear preference or aversion to certain options presented (Roy et al., 2009). A fixed choice preference test uses two or more stimuli to test for preference based on a directional response. This can be either a paired stimulus test or a multiple stimulus test, depending on how many different options are presented at once.

Fixed choice preference tests use operant conditioning to train the subject that their choice will lead to a particular outcome. Operant conditioning is a type of testing where an animal learns that a specific action, like pressing a lever or taking a certain pathway, leads to a certain consequence, such as receiving food or avoiding pain. This consequence is known as an unconditioned stimulus because the animal will naturally respond to it without any prior training, and they are usually instinctual triggers (Pritchett, 2004). An animal's behaviour is shaped by its consequences; positive outcomes increase the likelihood of repetition, while negative outcomes decrease it. Therefore, if an animal has a positive experience, it is more likely to repeat the action that caused it (Cartwright, 2002).

There are many variations of maze design preference tests, which involve the animal starting at the same point and deciding which path to take based on the stimuli presented at the end of each pathway. The main concept is that the subject can only pick one stimulus, and they cannot change their decision again for that trial. This gives a clear understanding of preference if an individual picks one pathway significantly more often than others.

Y- Maze and T- Maze Design

A Y–maze is a common test that allows an animal to choose between two different stimuli that are separated from each other by different pathways. It relies on the animal's short-term spatial memory as they have to pick one of two pathways that lead to their preferred choice of stimuli (Arnold & Hemsworth, 2013). This is a paired stimulus assessment as there are only two options available. The Y-maze consists of three arms, with the subject always starting at the bottom of the Y-shaped apparatus in the straight arm that connects to two diagonal ones (Fig. 2). This forms a 'Y' shape, and they must choose to go diagonally left or right.

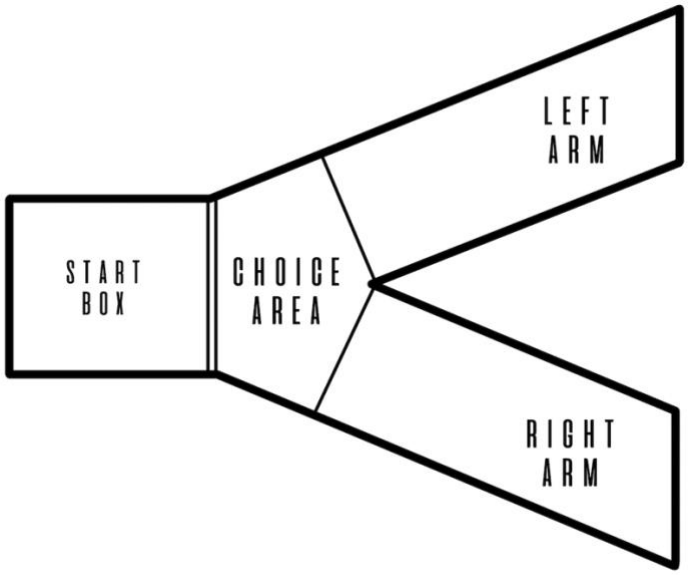

Figure 2. Schematic of a Y-Maze apparatus used for preference testing. Adapted from Arnold and Hemsworth (2013).

A T–maze follows the same concept except the individual must choose to turn directly left or right instead of diagonally (Fig. 3), making the shape of a 'T' (Habedank et al., 2021). The most common way of using this type of apparatus is to close the remaining pathway once the animal has made its choice (Deacon & Rawlins, 2006). Operant conditioning is used to teach the positions of the different stimuli. Once trained, each subject will learn that they can only make one choice and pick accordingly. This test can consist of multiple trials, but it can only compare a maximum of two different stimuli at once.

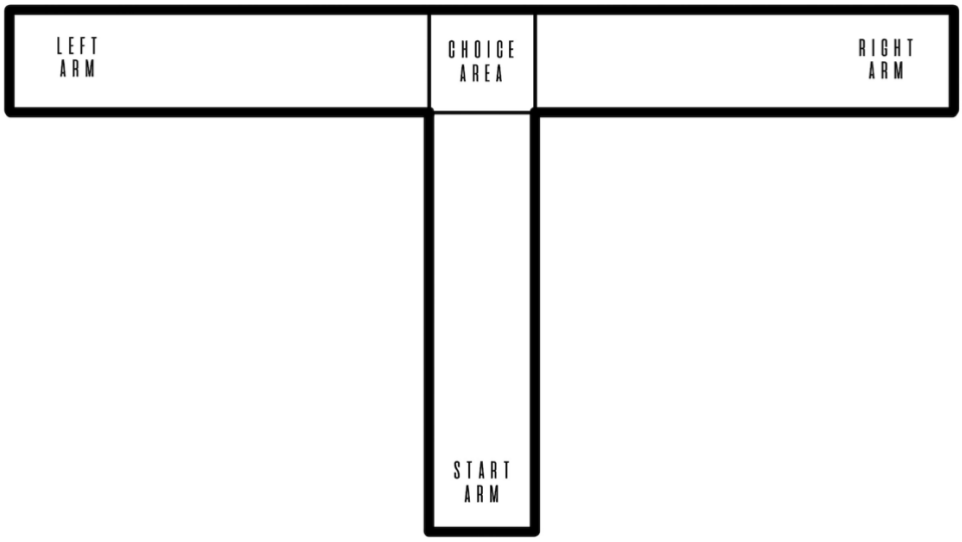

Figure 3. Schematic of a T-maze apparatus used for preference testing. Adapted from d'Isa et al. (2021)

Radial Maze Design

A radial maze can be used to test preference between numerous stimuli or environments at the same time (Hodges, 1996). The most commonly used is an eight-arm radial maze, which is used to test up to eight different stimuli at once (Fig. 4). This follows the same concept as the Y-maze and T-maze; however, it relies more on memory and cognitive abilities to navigate around as there are more pathways to choose from (Hodges, 1996).

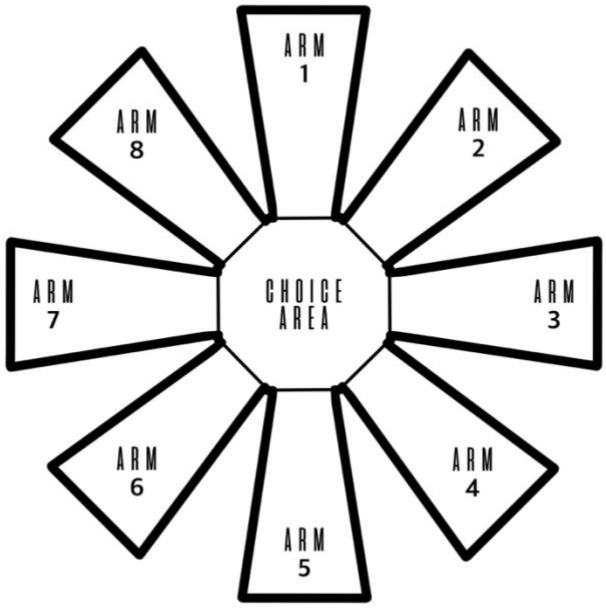

Figure 4. Schematic of an eight-arm radial maze apparatus. Adapted from Wang et al. (2007).

Radial mazes have commonly been used with rats (*Rattus norvegicus*) to test their spatial memory and cognitive abilities to navigate around the maze and find the desired outcome (Hodges, 1996). This method can be used for testing aversion and learning behaviours as well as preference. Rats tested in a radial maze using thirst as motivation were tasked to find the water in each of the eight arms, but some learnt before testing that not all pathways had water at the end. Over time, the rats learnt to avoid the pathways with no reward, showing a preference for rewarding pathways, and aversive behaviour to the ones that did not give them a desired outcome (Batson et al., 1986). Although this showed aversive behaviours and a pathway preference, driven by their goal to alleviate thirst, it relied heavily on memory and repetitive learning. A radial maze allows multiple stimuli to be presented at once; however, it is not commonly used to test preference in animals because it can be difficult for different species to learn and remember where each arm leads. This makes it harder to determine if the stimuli chosen were due to preference or lack of spatial memory (Olton & Samuelson, 1976).

Fixed Choice Test Benefits

Fixed choice preference tests, such as maze designs, are effective for evaluating preference in animals based on how many times a path or stimulus is chosen. These tests present a limited and clearly defined set of options, making them straightforward to measure and easy to compare across individuals and trials. It uses a basic method of operant conditioning, making it a strong method for measuring choice preference. Using a maze has been beneficial for studying 'place learning' in animals (Alves et al., 2007), where, over time, the animal will mentally map where the reward is after exploring the maze, and the paths are closed off behind them. Through repetition, they eventually learn the fastest way to reach their goal.

Motivation to find the reward is important for this association, as if it has little value, then the animal is less likely to work to find it (Warren et al., 2011). Preference can be assessed by analysing the choices made by each subject and how consistently they select a particular stimulus. If a stimulus is highly valued, such as in the trial in which rats were motivated by thirst to seek water (Batson et al., 1986), then it should be chosen at a much higher frequency than any of the other options. There may be some variation based on errors, such as navigation or anxiety-like emotion, which may interfere with the results, so we cannot say that the same stimulus has to be chosen 100% of the time for it to be a preference.

Fixed Choice Test Limitations

Maze tests can be limiting for testing preference based on the species and the time available for learning. Animals require a certain level of memory and cognition to be trained to use this type of test. This may limit the species it can be used for, and the number of stimuli that can be presented for animals that do not have the spatial memory to learn multiple different locations. Operant conditioning training is highly time-consuming; some species or individuals may be easier to train than others, or may make associative connections between their behaviours and the outcomes more quickly (Dragoi & Staddon, 1999). If a task is too difficult, an animal may get bored or not be able to figure out how to receive the reward.

Horses trained to memorise the location of their feed in a Y-maze (Murphy, 2009) required a lot of repetition and training. This can impair their performance and may lead to setbacks in welfare as high repetition without variation can cause frustration and mental fatigue, especially if the animal fails to understand what is being asked of them, or does not receive the desired reward (Jahangiri et al., 2019). If too much pressure and repetition is applied in a short span, it may also interfere with the preference test as it can lead to an emotional response rather than a preferred choice response. This preference test design is also better suited for testing subjects such as lab animals, where there is less of a time constraint, and they can be monitored consistently.

1.4.3 Free Operant Choice Methods

Free operant choice tests also involve presenting two or more stimuli or options at the same time, but unlike fixed choice tests, the subject has the freedom to continuously move between the options (Dawkins, 1977). Variables such as time spent, first visit, or number of times revisited for each stimulus or option are used to determine preference. This method is commonly used to test for preference between different environments. For example, in a study investigating whether dairy cows (*Bos taurus*) preferred to be outside during summer or winter, cows were given free access to both indoor and outdoor space for two hours a day, and the time spent in each environment was recorded (Smid et al., 2019). From this, cows were shown to prefer being outdoors during summer but showed little preference during winter. Similar studies have been done with domestic layer hens (*Gallus gallus domesticus*) to investigate what flooring they prefer (Hughes, 1976). This type of preference test is good for enhancing animal welfare as the outcomes can be used to improve husbandry practices and identify suitable animal enrichment strategies (Woods et al., 2020).

In addition to measuring the time spent with each stimulus, the types of interaction can also be used to assess preference. When studying the preference of substrate for laying hens (Hughes, 1976), researchers recorded not only the duration spent on each substrate but also specific behaviours, such as time spent roosting and the percentage of eggs laid on each substrate. These behavioural interactions are important when assessing preference for laying hens, as they spend a significant portion of their time performing these tasks (Weeks & Nicol, 2006). Understanding

their substrate choices helps ensure they can perform these behaviours comfortably, supporting positive experiences and improved welfare.

The amount of time spent with each stimulus and pattern of first choice can also help tell us about the relative preference for different options (Browne et al., 2011). If an individual spends all of their time with only one stimulus when it has access to numerous, we can generally assume that this is because they prefer that stimulus over all the others. If the individual has no preference, we expect that it may approach or interact with multiple stimuli, or not interact with any, showing a large variation in the results. For example, when assessing laying hens' preference for a battery cage or an outdoor run, the hens were given continual access to both environments and the amount of time spent in each was compared (Dawkins, 1977). The results showed no clear preference as hens spent a similar amount of time on both sides; however, we cannot tell how important or valued these environments are to them without further testing, as these might both be low-valued options, and they may prefer a third environment if added for comparison. From this study, it is unclear if the hens had more preference for one environment over another. Although there may be no distinct findings, the data gathered from this free choice method is still useful to understand how to improve the welfare of chickens regarding the Environmental Domain (Fig. 1). Showing no preference between the two options given still shows that further investigation should be done to understand what other options there may be to improve their standard of living.

Free Choice Method Benefits

Presenting stimuli using a free-choice method can show the relative preference because the participant is given multiple options at the same time and can interact freely between stimuli (Tanaka, 2003). Thus, if one stimulus is favoured and interacted with significantly more when all other options are still available, it can show a clear preference towards that stimulus over the other options.

In a free operant choice method, the interactions and time spent with each stimulus can be ranked, revealing which stimuli are most and least preferred. This allows for a more distinct understanding of preference within a population. In contrast, a fixed choice preference test,

where the subject can only select one stimulus per trial, can make ranking more difficult (Sen, 1973). While a fixed choice test is useful for identifying which stimulus is preferred, ranking preferences may provide a better understanding of preference and its strength. If an animal consistently chooses the same stimulus as a favourite, this suggests a genuine preference for that stimulus, and we should expect it to prefer that option if presented with other choices simultaneously.

Free Choice Method Limitations

Free choice preference testing can present challenges in identifying genuine preferences, as it typically involves a wider range of interactions compared to fixed choice tests. This variability makes it more difficult to determine whether behaviours are driven by true preference, random choice, or prior personal experience (Fraser & Matthews, 1997). If animals are unfamiliar with any of the stimuli, they are likely to interact with them all initially based on curiosity (Maia & Volpato, 2016). Although this exploratory behaviour may decrease after a few trials, it can influence the initial trial outcomes. Contrarily, if the stimulus is familiar to the subjects, they may show a biased preference simply due to familiarity, rather than a true preference (Fraser & Matthews, 1997).

To avoid these limitations, repeated testing and prior training with the stimulus can minimise differences in experience between all animals. Removing all similar stimuli prior to testing to minimise associations may also be advantageous. External factors such as location bias and emotional responses can also interfere with this method of testing. Even though the stimuli are presented simultaneously, they are still presented in a certain location that may lead to side bias and preference for surrounding factors rather than the stimulus itself.

1.4.4 Multiple Test Approach

Different methods of preference testing can be compared to determine if the results change when animals are exposed to the same stimulus under varying conditions. Outcomes may be influenced by factors such as learned behaviours or prior training (Baxter et al., 1983). For example, in a fixed choice maze test, animals typically require prior training to associate each pathway with a specific outcome, enabling informed decision-making based on their past experience and using

operant conditioning. In contrast, a free choice test using the same stimulus, but without prior training, would focus on spontaneous behavioural interactions. The data obtained from each method may differ due to the influence of training and test structure. Comparing results across both approaches can help determine whether their choices reflect genuine preference or are influenced by the testing method. Despite clear informational benefits, using multiple testing methods can be time-consuming and requires more subjects and resources. This approach may not always be practical and could negatively impact animal welfare if individuals are repeatedly subjected to testing procedures.

1.5 Assessing the Strength of Preferences

Assessing the strength of preference helps us to understand the importance of that decision for animals, and how much it affects their welfare if we provide or withhold it. If we do not provide something that an animal has a strong preference for compared to a weak one, it is more likely to impact their welfare negatively (Fraser & Matthews, 1997). A common method used to study the strength of preference is making the subjects work to access a preferred stimulus or avoid an aversive one. They are more likely to work harder to obtain something that they care about more, even if they are given another option that is easier to access (Dawkins, 1990). This was demonstrated in a study where calves (*Bos taurus)* were offered different types of roughage, accessible only by pressing a panel a set number of times (Webb et al., 2014). The calves pressed the panel more frequently to obtain preferred feed types such as hay and long hay, compared to less favoured options like straw or lucerne. Varying the required effort to access each type of roughage highlighted the calves' motivation to work for higher-value rewards. Using this information, we can infer that if we only ever provided calves with roughage like straw instead of hay, it would have more of a negative impact on their welfare than if we provided feed that they showed a stronger preference for.

1.6 Individual Versus Population-Level Preference

Preference can be evaluated at either an individual or population level. The preference of a single individual can be determined over multiple tests or trials to determine if they consistently favour a particular stimulus, indicating an individual preference (Martin et al., 2018). Whereas population preference uses average responses from a variety of individuals to determine general

trends across a group or species (Hernández-Arteaga & Ågmo, 2023). Both are essential for improving animal welfare by understanding differences between individuals and species, and developing tailored management strategies. For example, a study of dairy heifer feed preference based on time spent eating (Meagher et al., 2017) found there was a population preference for familiar feed. However, there was a strong preference seen in some individuals for novel feed. This gives insight into management techniques to cater for all the heifers by implementing a rotating feed schedule with familiar feed used the majority of the time, and substituting novel food occasionally to enhance enrichment and cater for the individual heifers that responded positively towards it.

1.6.1 Population Preference

Population preference is measured by studying a group within a species, analysing averages and common trends, and using this to draw conclusions back to the population. This usually requires a large sample size with varying factors such as breeds, age, and sex to accurately represent all individuals within the population (Hernández-Arteaga & Ågmo, 2023). Multiple individuals are exposed to identical stimuli under controlled conditions across repeated trials. Measured variables depend on the method; in free-choice tests, common metrics include time spent, first-choice frequency, and latency to approach. In fixed-choice tests, the main variable will be first choice frequency, as there are limitations to measuring other variables when only one option can be selected per trial. Population preference can be used to gather information relative to a species or to focus on a particular subgroup. For example, when examining substrate preference in laying hens (Hughes, 1976), the main objective was to guide husbandry practices specifically for the population subgroup of laying hens, based on their roosting and laying behaviours. In contrast, an investigation into the fruit colour preferences in two species of *Turdus* (Larrinaga, 2011) aimed to assess both intra- and interspecific variation. Due to physiological and behavioural similarities, a mixed-species sample was used to identify shared colour preferences across the population of two closely related species. Despite different population sizes and methods of testing, both methods analysed individual behaviours and used statistical analyses to draw conclusions based on the overall mean and trends.

Factors Influencing Population Preference

When testing population preference using a sample group, the group size, diversity and learning abilities needed to be taken into consideration. A study using wild red fronted Lemurs (*Eulemur rufifrons)* investigated their learning ability and preference to either pull or push a door to receive food from a box (Schnoell & Fichtel, 2012). This was done with separate study groups, one of which was previously taught how to open the door, and the other with no prior training. The results showed that both groups had a high success rate for completing the task, but they had different preferences for what technique they used to receive the food, based on whether they had previously undergone training. The group with pre-training preferred the method they were taught, whereas the group with no training showed no overall group preference. The lemurs also had a different success rate based on their sex (Schnoell & Fichtel, 2012). The outcome of this study shows that prior learning and group diversity is important. It would be difficult to say that the population has a preference if only one sex or age were used, as it would not represent the entire population accurately.

Sample size is critical for population preference, as if the sample size is too small, the results will not be adequate to represent the population (Taborsky, 2010). However, obtaining a sufficiently large sample can be challenging in animal research due to ethical constraints and the need to minimise welfare impacts. Sample size should be large enough to obtain sufficient data, but follow the guidelines of the '3Rs': Replacement, Reduction, and Refinement in animal ethics and research (Hubrecht & Carter, 2019).

Outside factors also need to be taken into consideration when analysing population preference. Housing and physiological state can influence preference in a sample group. Preference can be driven by goal-directed behaviour (Warren et al., 2011); therefore, the mental state of the subjects may alter their choice behaviour. If all subjects are fasted before studying food preferences, their choice may be different from the wider population that has access to food prior to and is given the same options. The price the subject is willing to pay for the reward is higher if they are feeling unpleasant emotions such as hunger, boredom or thirst that drives them to alleviate that feeling (Dawkins, 1990). This needs to be taken into consideration when referring back to a population that may have different physiological pressures. Similarly, you would not

use research animals born in a lab to study the behaviour of wild animals of the same species (Hernández-Arteaga & Ågmo, 2023). Their environmental pressures would be significantly different, so they would not effectively represent the population and would have different preferences based on their personal experiences and survival instincts.

1.6.2 Individual Preference

Individual preference is measured by observing the choices and behaviour of one subject over many trials. The data is used to determine any consistent patterns within the individual to understand what they value or avoid the most (Castilho et al., 2020). All animals have unique personalities, experiences, and intellectual abilities that may influence their preferences (Dingemanse et al., 2005). As a result, some animals may exhibit clear individual preferences that are not reflected at the population level. Whilst studying the sexual preferences of jumping spiders (*Hasarius adansoni)* (Castilho et al., 2020), both population and individual preferences were analysed. The study found no population-wide preference for male body size; however, individual females displayed strong, consistent preferences, some exclusively choosing large males, whilst others only selected small males to mate with. These results suggest that phenotypic preferences vary significantly among individuals, and that assuming a uniform preference across the population may be misleading. Recognising individual variation can contribute to improved animal welfare and support population growth, for example, by tailoring for individual needs through breeding decisions and enrichment.

When determining the housing preference of dairy cows (Smid et al., 2019), the study group generally preferred being outdoors during summer. However, individual preference was not examined, and if a subset of individuals had negative experiences associated with the outdoor environment, such as discomfort or anxiety, enforcing outdoor access could adversely affect their welfare. While population preference can guide improvements in husbandry practices across a species, individual preference needs to still be accounted for to refine welfare strategies that benefit all subjects and help us to understand where and why variation in preferences may occur.

Factors That Influence Individual Preferences

Age, breed and experience can influence individual preference through their motivation and goal-directed behaviours (Simitzis et al., 2006). A link between age and cognitive performance in dogs was found (Watowich et al., 2020), showing that critical cognitive abilities change through stages of their life, and the memory and decision-making of young puppies will vary from that of a geriatric dog. Younger animals are often more excitable and curious, exhibiting more exploratory behaviours. In contrast, older dogs may prefer familiar environments and have less motivation to explore novel stimuli (Watowich et al., 2020).

Prior learning and experience influence preference, as evident when studying colour and shape preference of domestic chicks (*Gallus gallus*) (Protti-Sánchez et al., 2023). Newly hatched chicks that had no previous learning or experience had an innate preference for similar colours and shapes, whereas chicks that had been exposed to a bitter taste when presented with a colour learnt to avoid that choice, and showed a different preference based on their learning.

Morphological and genetic differences between breeds may also contribute to preference. For example, dogs bred to hunt would most likely show a different preference for toys and other stimuli than farm dogs, as they were bred for different working styles and would have variations in their goal-directed behaviours (Heberlein et al., 2017).

Animals raised with different environmental pressures may develop distinct variations in preference (Baxter et al., 1983). Layer hens were studied to determine their preference between wire and litter floors using both a free-choice method and fixed fixed-choice method (Hughes, 1976). The free-choice test results found that hens that had been reared on litter flooring spent more time on the litter than hens that were reared on wire flooring. This highlights how preference is influenced by experience, and that we might find different preferences if studying hens with no prior experience of either substrate.

1.7 Considerations When Determining Preference

Preferences are only ever relative to the options presented, and animals may choose differently when presented with additional or alternative stimuli. Limited options can lead to a preference

for one item, but this does not indicate how meaningful that preference is. A choice between two low-value options does not reveal whether the preferred stimulus would still be chosen if another option were presented that may hold a higher value.

In a study investigating lambs' *(Ovis aries)* preference for floor type (Wolf et al., 2010), lambs preferred woodchips over straw, which was a suitable environment for their growth. However, this did not tell us if the lambs would exhibit a stronger preference for another substrate if given the option.

This highlights that preference tests do not always measure how much an animal values a stimulus. True preference can only be established if animals consistently select the same option across multiple trials with varied high-value choices (Sen, 1973). When assessing preference for animal welfare practices, it is crucial to confirm there is a true preference before implementation to ensure improvements in quality of life. Without evaluating a comprehensive range of options or demonstrating consistent choice behaviour, there may be insufficient findings to suggest that there is a genuine preference that will positively influence animals' welfare and enrichment.

Animals' preferences may change over time due to internal motivation and development. Thus, momentary differences in choices may also affect the overall results of preference, leading to more variability (Maia & Volpato, 2016). For a genuine preference, we would expect to see the same choice every time; however, we do not know that an individual's preference has not changed for various reasons. To account for these potential changes, repeat testing should be done over a length of time, and any outliers or sudden discrepancies should be reviewed with consideration to their natural or learnt behavioural changes that may have caused this.

Since animals' preference is influenced by how individuals perceive their environment, it is important to consider differences in sensory capabilities, such as olfactory, auditory, and visual inputs, at both the individual and population levels (Stevens, 2013). These physiological factors can vary between species and among individuals, influenced by their biological and environmental conditions. This affects how stimuli are perceived, valued and the behavioural response they may elicit. It is common for researchers to use humans as a baseline comparison

for animal research because it is easier to understand; however, this needs to be navigated carefully, as there are vast physiological differences between humans and other species (Brebner et al., 2024). Thus, when investigating preference in animals, the experimental design should be tailored to their species-specific sensory and behavioural characteristics to better understand their perspective, while also considering individual variation within the species.

1.8 Vision in Dogs

Different species rely heavily on different senses such as olfactory, hearing and vision, depending on their environmental pressures and behaviours (Stevens, 2013). In many mammals, visual perception is important for survival; however, due to different environmental and morphological adaptations, most species perceive the world very differently from humans (Raz & Breitkopf, 2007). Dogs are classed as mammals, part of the order Carnivora. They are predators, derived from wild ancestors who relied on their hunting skills for survival (Morey, 2010). Through domestication and selective breeding, dogs are now the most morphologically diverse species to exist (Byosiere et al., 2018). Over time, dogs have become a product of human interference, selectively bred for different appealing traits such as doing specific jobs, or for their physical attributes like their coat type, size, or facial characteristics (Serpell & Duffy, 2014). There are now over 200 recognised dog breeds (Hebdon et al., 2025), each with distinct shapes and sizes that would never be seen in wild canines and are significantly different from their ancestors (Drake & Klingenberg, 2010). These morphological differences mean that various breeds may experience things differently, and through continuous selective breeding, how dogs perceive the world may continue to change.

However, visual traits adapted for hunting and tracking remain prominent in many breeds. Their sensitivity to light conditions, visual depth and motion detection, which are ancestral traits they adapted for survival as predators (Barber et al., 2020), are enhanced, exceeding those of humans (Miller & Murphy, 1995). Because they rely heavily on motion detection, including in low light conditions, dogs lack the visual acuity and colour perception that other mammals, such as humans, rely on (Neitz et al., 1989).

There are only two types of photo receptors in the mammalian eye: rods and cones (Gregg et al., 2013). These photo receptors convert light energy into electric signals, which travel through the eye and stimulate the ganglion cells in the form of action potentials, and progress through the optic nerve, sending information to the brain to interpret images (Mehra & Le, 2019; Moazed, 2023). Rods are sensitive to low light and are crucial for scotopic (nighttime) vision; they do not contribute to colour perception or high-resolution details. In most mammals, including humans, rods contain only a single photopigment and make up about 95% of the photoreceptors in the retina (Lamb, 2016). In contrast, cones are made up of two or more different photopigments, each of which reacts to different wavelengths of light, resulting in colour vision. Cones only make up 5% of the eye photoreceptors, but they operate more frequently and under varying light conditions (Lamb, 2016; Purves et al., 2001).

The human retinal ganglion cell has three channels that transfer information from the eye to the brain using signals from the photoreceptors. Each channel works independently and processes different information, but it is all transferred through the thalamus to the visual cortex, where it is interpreted (Gegenfurtner, 2003). Colour perception is formed from the brain interpreting the relative stimulation of different light absorption from different wavelengths. The brain perceives colour based on the combined input from the cone photoreceptors. Each cone type responds to a range of wavelengths, and their overlapping sensitivities enable the brain to distinguish between various colours and interpret different blends and shades (Purves et al., 2001).

1.8.1 Visual Acuity

Dogs generally have poorer visual acuity than humans. Visual acuity refers to the clarity with which an object can be seen and the ability to distinguish fine details (Kalloniatis & Luu, 2007). Acuity is dependent on many features such as the anatomical structure of the eye, the brain's ability to interpret visual signals, and environmental conditions such as illumination and contrast (Byosiere et al., 2018; Kalloniatis & Luu, 2007). The average human acuity is generalised as 20/20 vision. This means the average human has full clarity of an object when twenty feet away (Holladay, 2004). In contrast, studies have found that the visual acuity of dogs on average is 20/75, meaning that dogs can only clearly discern an object that is twenty feet away that most humans with normal vision could clearly see at 75 feet (Byosiere et al., 2018). Similarly, a

comparative study using both humans and dogs on their ability to identify patterns in varying light resolutions found that humans could discriminate objects up to three times the distance of the dogs in both dim and bright light (Lind et al., 2017).

The main cause of lack in visual acuity in dogs is thought to be due to the structure of the retina (the light-sensitive tissue at the back of the eye), rather than any visual inputs or signaling sent to the brain (Miller & Murphy, 1995). Specifically, dogs do not have a fovea centralis, which most primates, including humans, have in their retina. The fovea centralis is an area containing a high density of cone photoreceptors connected to ganglion cells and interneurons (Beltran et al., 2014). This structure is located within the macula, a central region of the retina containing both rods and cones, where the high cone density and direct connections to the ganglion cells support acuity, colour sensitivity, and binocular vision, particularly in well-lit conditions (Beltran et al., 2014; Kolb, 1995).

In humans and some other mammals, the fovea centralis is a rod-free area, with a high density of tightly packed cones. By having no rods, the light is able to saturate all the cones, improving acuity, fine detail visibility, and colour discrimination with a 3-dimensional depth (Kolb et al., 2020). Dogs do not have a fovea, but they do have a higher cone density area within their visual streak called the area centralis, a horizontal band of retinal tissues where photoreceptors are more densely packed than anywhere else (Yamaue et al., 2015), which, unlike humans, contains both rods and cones.

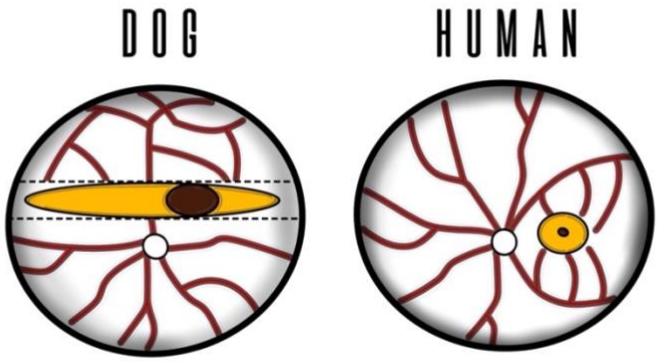

Figure 5. The visual streak in dogs, including the area centralis, compared to the fovea in humans, located in the macula. Illustration Adapted from Günter et al. (2024).

This structure allows dogs to have clearer acuity across a horizontal field, enhancing motion detection and the ability to spot prey. However, this comes at the trade-off of acuity for fine details and distinguishing objects further away (Fig. 5). Without a fovea, dogs' retinas have a more even distribution of photoreceptors horizontally across the retina, with ganglion cell density maxima ranging from 6,400 to 14,400 cells per mm^2 in dogs (Peichl, 1992). In comparison, the fovea in humans contains up to approximately 38,000 cells per mm^2 (Curcio & Allen, 1990).

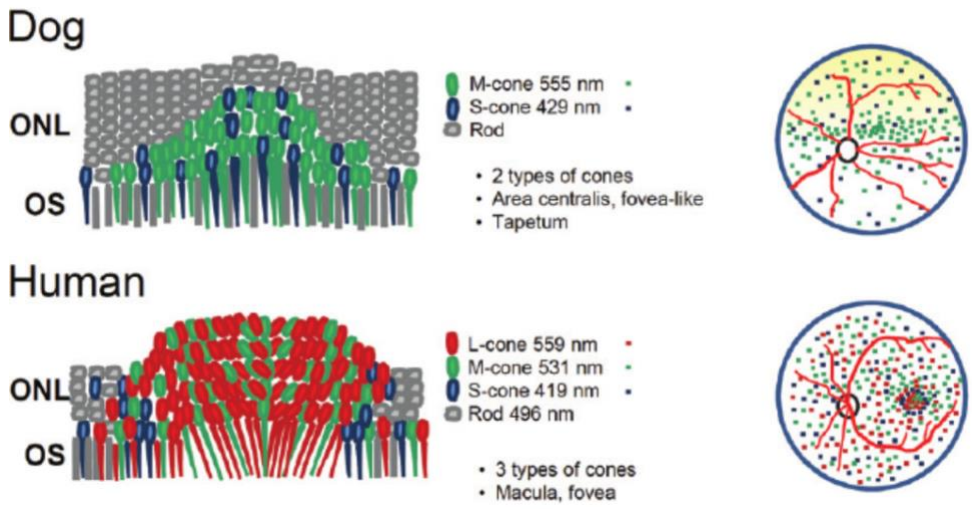

Figure 6. Rod and cone distribution in the dog and human retina; ONL: outer nuclear layer; OS: outer segment. Different cone wavelengths (L, M and S) represented by different colours (Kostic & Arsenijevic, 2015).

The spatial density of rods and cones in humans was measured and used to construct maps of the photoreceptor densities (Curcio & Allen, 1990). It was found that humans have an average of 4.6 million cones within their retina, with a large portion found in the fovea centralis. In comparison, dogs have no area centralis in their eye; however, they have more rods that are present throughout their entire retina for better vision in low light (Barber et al., 2020). Research has shown that even in the highest cone density area for dogs, they are still rod dominant (Kemp & Jacobson, 1992). The number of rods in the canine eye overall is much greater than in humans (Fig. 6); thus, the high saturation of rods within the canine retina means dogs are highly adapted to improved performance in various light levels, but the lower cone density limits their acuity and colour vision.

This adaptation for scotopic vision is also enhanced by the presence of the tapetum lucidum, a reflective layer located behind the retina that is prominent in many mammals and invertebrates (Miller & Murphy, 1995). This layer of tissues enhances vision in low light by acting like a mirror and reflecting incoming light back through the retina, providing a second opportunity for photoreceptors to absorb more light, enhancing their stimulation and visual sensitivity (Wallig et al., 2018). The tapetum lucidum can be seen in animals at night, characterised by their distinctive reflective shine or 'glowing' eyes, as seen in dogs.

1.8.2 Depth Perception and Field of View

Dogs rely on movement tracking and light for visual depth perception. The poorer visual acuity and lateral placement of the dog's eyes result in a narrow binocular overlap of between 30- 60 degrees, varying based on skull shape (Byosiere et al., 2018). The physiological traits result in limitations regarding their binocular depth perception (stereopsis). Depth perception is how we are able to view the world in three dimensions, when both eyes have an overlapping field of view, merging different perspectives to create one image and perceive distance accurately (Tyler & Scott, 1979). Dogs only have a small area of depth perception and are thought to see best directly in front of them, above their nose height, and straight ahead. Different breeds have factors that implicate this, such as skull shape, nose length, eye width and ear shape and size (Barber et al., 2020). Dolichophallic dogs (such as Greyhounds and Dobermans) have longer noses, which can interfere with their overlapping vision, resulting in poorer depth perception than brachycephalic breeds, which have short noses, but whose eye socket depth and placement mean that they have a shorter field of vision. A study investigating the relationship between skull size and ganglion density found that the distribution of ganglion cells and presence of the visual streak varied with skull size (McGreevy et al., 2003). Dogs that had shorter skulls, such as Pugs and Chihuahuas, had virtually no visual streak and a much more prominent area centralis, meaning their monocular and binocular vision would differ from dogs with longer skulls. It is thought that because of the different visual composition, brachycephalic dogs have better visual acuity, but dolichocephalic breeds have better motion detection and an improved field of acuity along the horizon (Barber et al., 2020).

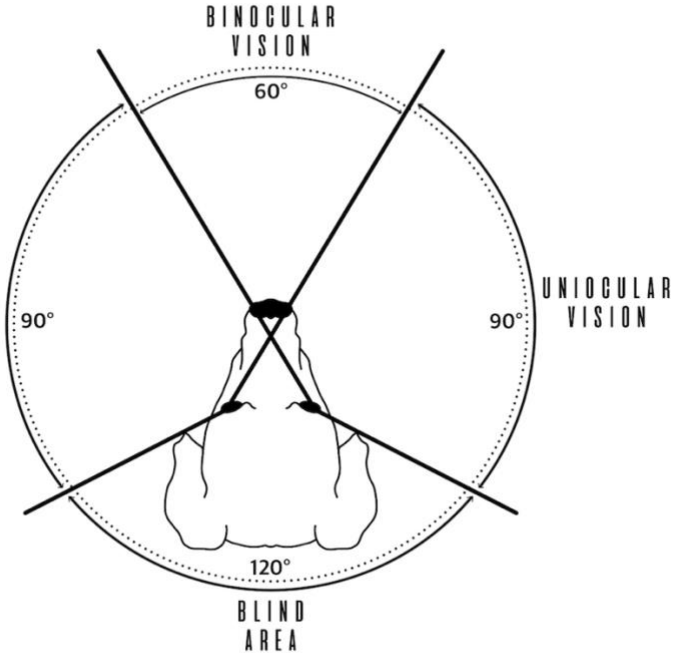

Figure 7. The binocular and uniocular field of vision of an average mesocephalic (medium–skulled) dog: 60° binocular field, 90° uniocular per side, and a 120° blind spot behind. Adapted from Miller and Murphy (1995).

Despite the differences between breeds, the small area of binocular vision for all dogs means that they cannot rely on stereoscopic depth cues, but instead they depend more on detecting movement and light intensity for spatial recognition (Byosiere et al., 2018). A study suggests that dogs can detect moving objects that are up to 900m away, but they can only detect stationary objects up to 600 m (Lõoke et al., 2020). This is thought to be beneficial for tracking prey and detecting threats or changes within their environment to react quickly (Huber et al., 2023).

Dogs' morphological head structures may be disadvantageous for depth perception, but are compensated through their large field of vision, significantly exceeding that of humans, with a visual field of approximately 240 degrees (Fig. 7). This wide field supports vigilance and the ability to detect movement across large areas of the environment. Being able to see and react quickly to movement from many different angles is more beneficial towards their survival in the

wild than binocular vision. Dogs can still assess depth; they just rely more on motion and light detection, using contrast, shadows and brightness to estimate distance (Byosiere et al., 2018). This may not provide the same accuracy, but it is advantageous for complex navigation and detecting prey in low light.

1.9 Colour Vision in Dogs

Dogs have fewer cone photoreceptors than humans, limiting their ability to react to different ranges of light wavelength. Humans have three different cone photoreceptors within the retina of their eye responsible for colour vision, whereas dogs only have two photoreceptors (Fig. 6). Wavelength is measured in nanometres (nm), and the human eye is sensitive to light between approximately 400 nm (violet) and 700 nm (infrared) (Konatham et al., 2021).

The three types of human cone receptors react to different wavelengths, resulting in our visible colour spectrum. The L-Cones (red) react to low-frequency light wavelengths, S-Cones (blue) react to short-frequency light wavelengths, and M-Cones (green) react to medium-frequency light wavelengths (Roorda & Williams, 1999). Sensitivity to light, also referred to as spectral responsivity, is often measured in amperes per watt (A/W) and indicates how strongly a photoreceptor responds to different wavelengths (Hawryshyn et al., 2006).

The pathways from the retina to the visual cortex that result in colour vision are the same in most species, including humans and dogs. However, the difference in cone photoreceptors and their spectral sensitivity changes the visual output. Dogs only have two wavelength sensitivity peaks. Unlike humans, who possess three types of cone photoreceptors (trichromacy), dogs are dichromatic, meaning their colour vision relies on just two types of cone photoreceptors. These cones are S-cones, which react to short-frequency light wavelengths, and ML-cones that respond to medium to long-frequency light wavelengths (Mowat et al., 2019) (Fig. 8). This results in poor visibility of many colours that are only visible to humans due to the presence of L-cones, which are absent in dogs (Barber et al., 2020).

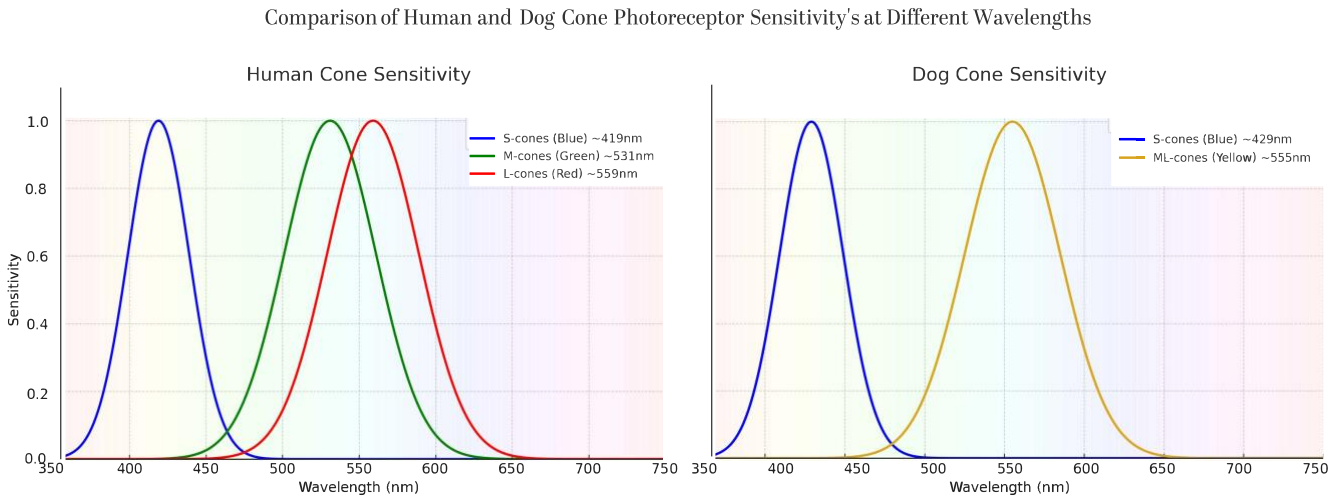

Figure 8. Comparison of cone photoreceptor sensitivity in humans and dogs. Humans have three cone types: S (419 nm), M (531 nm), and L (559 nm), enabling full trichromatic vision. Dogs have two cones: S (429 nm) and ML (555 nm), giving them limited dichromatic vision mainly in blue-yellow hues. Illustration based on Neitz et al. (1989); Solomon and Lennie (2007).

The cones that dogs possess are thought to detect highly saturated colours that humans characterise as yellow (ML-cone) and blue (S-cone). The S-cones in dogs have a sensitivity peak estimated at 429 nm, while the ML cone has a longer wavelength sensitivity peak, at 555 nm (Neitz et al., 1989). These two photoreceptors do not overlap, leaving gaps in their ability to absorb light at intermediary wavelengths. This means dogs cannot distinguish between colour wavelengths within those gaps (Neitz et al., 1989). Instead, dogs have a narrow region within their visual spectrum known as their spectral neutral point, when both cone receptors are simultaneously stimulated equally. This causes the blended colour to be indistinguishable to dogs and perceived as shades of grey (Neitz et al., 1989). The spectral neutral point in dogs is at around 480 nm, between the small overlap of both cone receptors (Fig. 8), where humans would perceive the colour to be a light blue/green.

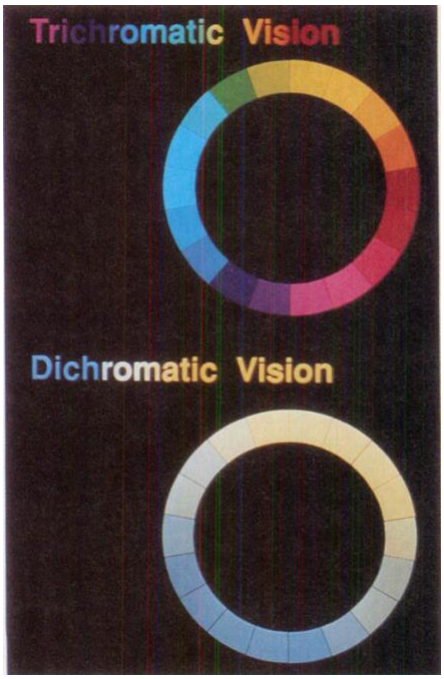

Figure 9. Comparison of the Trichromatic colour spectrum (top), commonly seen in humans with normal vision, and the Dichromatic colour spectrum (bottom) of canines. Used with permission of Miller and Murphy (1995).

The lack of cone receptors in dogs' vision and little overlap in the cone wavelengths means that dogs cannot see the colours we would perceive to be green or red. Thus, dogs are thought to be red-green colour blind, and instead they see brown and grey hues (Fig. 9). The main difference between human and dog vision is that dogs are unable to distinguish between colours with middle-to-long wavelengths, which include green, yellow-green, yellow, orange, and red; these shades all appear as different hues of yellow to them (Miller & Murphy, 1995). Similarly, the peak sensitivity of the medium-long wavelength cone means dogs cannot see varying shades of blue or purple. While dogs may have limited colour perception, this does not mean that they cannot still form preferences based on the colours they can perceive within their wavelength range.

1.10 Testing Colour Preference in Dogs Based on Their Colour Spectrum

Dogs may still have preferences based on visual perception, even though they rely heavily on their other senses. Vision may not be canines' primary sensory input that they rely on, but they do still constantly use their sight, and domesticated dogs seem to use it more than their ancestors for recognising human faces, emotions and body language (Huber et al., 2023; Siniscalchi et al.,

2018). Therefore, vision still plays a functional role in shaping canine behaviour, and they may have more preferences towards visual stimuli than expected based on their perceptual capabilities.

Dogs can discriminate between yellow and blue light wavelengths as they are highly saturated colours in their vision. Thus, they may have a preference between objects of these colours rather than objects they perceive as colourless or neutral. When a group of untrained dogs were given different shades of dark and light yellow and blue coloured paper to choose from, the results suggested that they were able to discriminate between the different shades and relied more on the colour than the brightness levels to make an informative decision and choice of stimuli (Kasparson et al., 2013). Similarly, the effects of luminance on dogs' ability to discriminate between colour on a computer screen were investigated, the findings indicated that dogs were able to discriminate between colours better in certain luminance levels, and they were able to detect individual colours more when presented on achromatic (grey or neutral) backgrounds rather than against other colours as backgrounds (Byosiere et al., 2019). This suggests that varying light conditions and colour contrasts may influence dogs' ability to discriminate between colours. Although dogs lack cone receptors to see reds or greens, they were still able to differentiate between these hues as different shades when they were presented at their highest colour saturation. Thus, dogs may use information from both their rods and cone photoreceptors to interpret visual stimuli.

Dogs have peak sensitivity to absorb light wavelengths that correlate to the colours yellow and blue; therefore, not only are dogs able to discriminate between these different hues, but they also would stand out more prominently in the environment compared to any other colours (Byosiere et al., 2018). The high visibility of these colours leads to increased contrast between coloured objects and their natural environment, which is usually green or brown, which dogs would see all as achromatic colours. They would therefore be better at detecting yellow and blue toys or objects, which could promote play and foraging behaviour (Neitz et al., 1989). This may lead to a colour preference based on more positive associations with these colours that are highly visible to them.

Little research has been done on colour preference in dogs. One experiment showed that when presented with the choice of blue and yellow food bowls, there was a population preference towards the yellow bowls (Roy et al., 2024). This, however, was not compared to other colours that trichromatic mammals can see but that dichromatic animals like dogs cannot, and it used a population of free-ranging dogs in varying environments, with each dog only tested once. The lack of a controlled environment makes it harder to determine if other external factors were influencing their decision-making, and what prior experience the dogs may have had as they were tested within their home range, which differed between the dogs. Free-ranging dogs may also have varying drives and show different goal-directed behaviours, such as motivation for food. By only testing each dog once, it is difficult to say this was a preference, and not just their first choice, based on curiosity for the more visible object. The results would likely change if the test were repeated with each dog more than once, and the strength of preference was tested on the same dogs.

Another study investigated if dogs had a preference for feeding toys made of natural rubber, and if there was a scent and colour preference among these toys using the options of yellow or blue (Boonhoh et al., 2024). The results indicated that dogs had a preference for yellow over blue; however, because the main aim of the study was not focused directly on their colour preference, it lacked the controls of other colour options, and it was also based purely on owners' observation of their dogs at home. Preference was determined by which of the two toys owners saw their dog sniff first, and if they sniffed one toy two out of three times, it was considered to be a preference. The minimal trials required to be considered a preference make it harder to determine if it is a true preference or just chance. There is also room for human error by relying on owners' observation, who may be biased, and there is no control between the measurements taken from the different dogs participating. From these limited studies, there seems to be a pattern of yellow being favoured over blue; however, both studies had significant limitations, such as the lack of experimental controls and very low thresholds for defining a preference.

1.11 Research Aim

This research aims to evaluate if dogs show a colour preference between blue, yellow, and red. Blue and yellow food bowls will be used to evaluate a preference between the two highly

saturated colours within their colour spectrum, and a red bowl will be used as a control, as it is known to be a colour not visible to dogs.

This aim will be addressed using a free-choice preference testing method. This method has been selected because it can show not only whether individual dogs have colour preferences but also provides information on the strength of any preference expressed without relying on the dog's ability to remember an association between the stimulus and a reward to express its preference. Dogs will not require training before testing, so they are less likely to choose a colour based on learnt experience. Testing will be done in a controlled environment, minimising external factors that may influence results, and for consistency for all individuals. This free choice preference testing method allows data to be gathered at both a population and individual level, determining if there may be a common preference for the dogs overall, or if there is variation between dogs, and how individuals may exhibit these preferences differently from one another. Previous similar studies (Boonhoh et al., 2024; Roy et al., 2024) indicated that dogs did have a preference for yellow coloured stimuli over blue, and we would expect that if this population preference was true, the dogs used in this study would exhibit a similar preference. However, it will be interesting to investigate if the results differ when adding a red stimulus for comparison and in a more controlled environmental setting.

2. Materials and Methods

2.1 Animals and Care

Recruitment

Dogs were recruited from Palmerston North and the wider Manawatū region to reduce travel time to the research facility at Massey University. All procedures were approved by the Massey University Animal Ethics Committee (MUAEC 24/41). An online questionnaire (Appendix A) was developed to gather relevant information about each subject and assess eligibility.

Inclusion Criteria

All breeds were considered, except for brachycephalic (short-nosed) breeds due to morphological differences and the potential influence these may have had on the outcomes. Additional eligibility criteria included:

- Aged between 1 and 10 years old
- Comfortable in unfamiliar environments
- Comfortable being around new, unfamiliar people
- Comfortable travelling to and from the research facility
- Tolerated being separated from their owners for short periods (during testing)
- Could attend a minimum of one habituation session and three test sessions at Massey University
- Free of medical conditions, specifically dental or visual, that may interfere with their performance in the test
- Comfortable using either the stairs or the elevator to reach the testing room

Owners were required to read a recruitment information sheet (Appendix B) outlining the details of the study and complete the online questionnaire for each dog.

A total of 27 questionnaire responses were received. After applying the inclusion criteria, 16 dogs were selected to proceed with the habituation trials.

2.2 Description of Research Facility

The study was conducted in a research facility at Massey University. The test area consisted of a waiting room connected to a testing room. A separate room, located adjacent to the testing room and accessible only to staff, was used for food preparation. Dogs arrived with their owners and entered the waiting area, where they remained between trials. The waiting room was designed to be a low-distraction environment, containing a water bowl for the dogs, a desk for equipment, and chairs for the owners.

The testing room was approximately 50 m^2 with a sink unit and two large fish tanks along the back wall. Two Sony Handycam HDR-CX405 were set up on tripods out of reach from the dogs so they could not knock them over, at each side of the room. One camera was on a bench facing the entrance door, and the other was on the far left side of the room on a high shelf. These angles allowed a clear view of all bowls and the dogs' interactions in the room with minimal blind spots. All other furnishings were removed to minimise distractions. Before each test session, three different coloured bowls (red, blue and yellow) containing an equal portion of the dog's usual food were placed at equal distances from the doorway leading into the test room.

During tests, the dogs would enter the testing room from the waiting room, and the door was closed behind them, with the researchers and owner remaining in the waiting room. The dogs were observed from the waiting area during testing via a live feed camera set up in the testing room. The main purpose of this footage was to observe the dogs' behaviour live for any increased signs of fear or anxiety, as well as for manually recording information as a backup in case there were any technical errors with the cameras' recording in the testing room.

Only one dog at a time was brought into the facility. The floors were swept and washed between dogs, and the water bowl was emptied, cleaned, and refilled.

2.3 Habituation

Before participation in either the pilot or main study, dogs underwent a habituation period to ensure they were comfortable with the facilities and the test procedure. Habituation is a form of learning in which, over time, there is a reduced response to the stimuli. It was important that the

dogs felt comfortable before participating in the study, to protect their welfare and to reduce any emotional responses that could interfere with their performance during testing.
We used the 'Fear, Anxiety, and Stress' (FAS) scale for dogs (Fig.10) to determine whether a dog was considered habituated and suitable for participation in the study. Dogs that showed severe levels of fear or anxiety at any stage (FAS 4-5) were immediately removed for the safety of both owner and dog. Dogs showing moderate or mild symptoms (FAS 2-3) were given another habituation session to see if there was any improvement. If there was little or no change after three sessions (the pre-determined maximum), dogs were excluded from the study. Dogs had to be showing no more than subtle signs (FAS 0-1) to proceed to testing.
The owners were permitted to give their dogs treats during habituation to help form a positive association with the novel environment, a form of operant conditioning.

Each dog was observed upon arrival, in the elevator, the waiting room, and the test room with the owner present. Dogs were given a maximum of three attempts to comfortably enter all areas of the facility, to avoid causing excessive stress or anxiety. If the dogs successfully showed signs of habituation in every room, without showing any increasing signs of concern based on the FAS scale, they would proceed to explore the testing room without the owner or anyone else present. Food was scattered on the floor to create a positive association with the space through positive reinforcement, and to imitate what they would experience during testing. If the dog showed disinterest in the food or signs of distress (e.g., vocalisation, scratching, stress-related body language), they were either rescheduled for another habituation session or removed from the study.

Habituation sessions lasted 20–40 minutes. Dogs that did not habituate or continued to demonstrate high levels of fear or anxiety over three visits were excluded. The owner could also withdraw their dog at any point.

Following habituation, 15 of the 16 dogs were selected to continue. Of these, two were allocated to the pilot study and 13 to the main study. The dogs were homed with their owners and only brought into Massey University for their testing days.

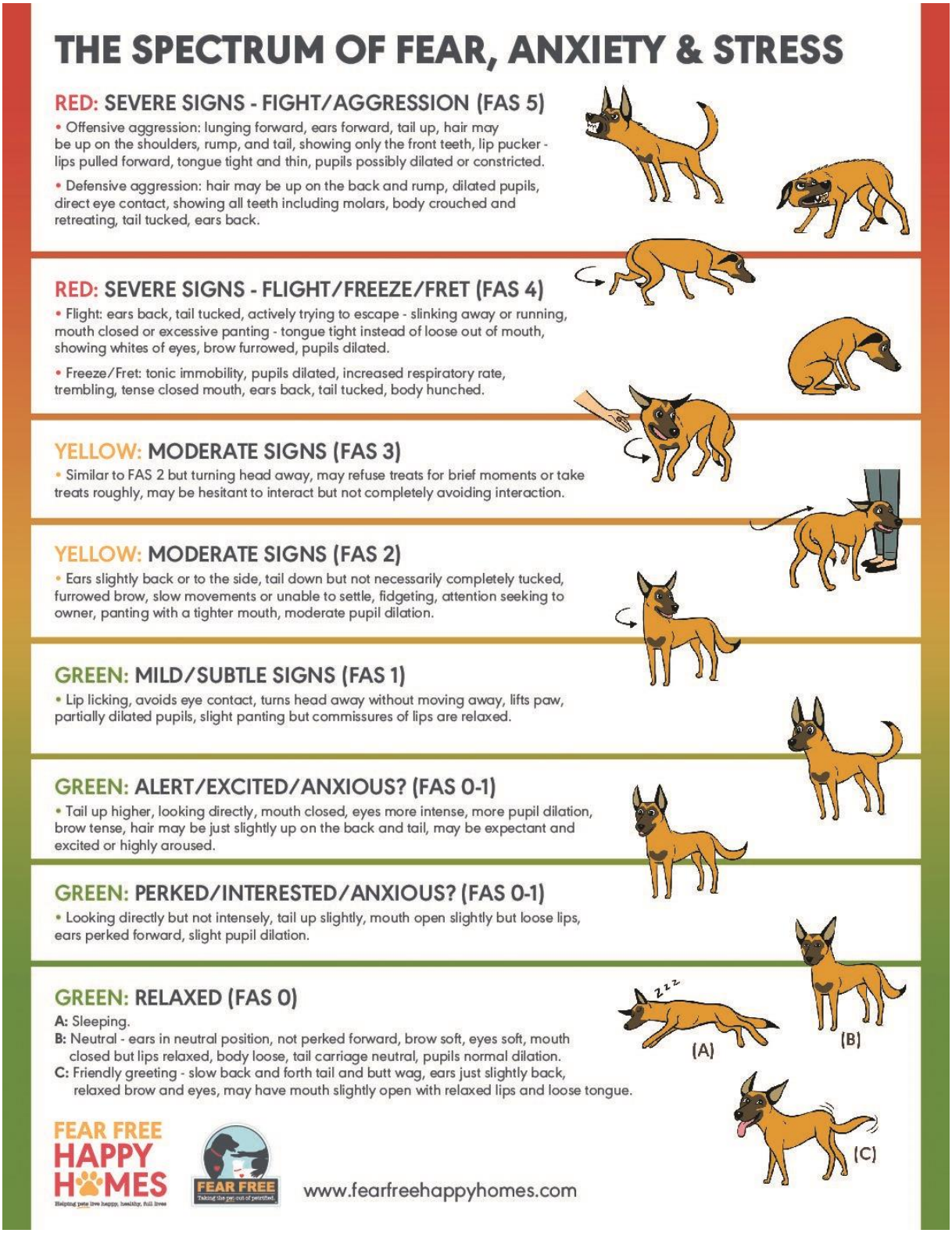

Figure 10. The spectrum of fear, Anxiety and stress for dogs (Homes, 2025).

2.4 Experimental Procedure

Pilot Study

A pilot study was carried out using two dogs to refine the parameters for the main study. Following habituation, each dog only had one test day, consisting of six consecutive trials, one for each bowl colour combination. During the pilot study, the following variables were assessed to optimise the final study design:

- Time spent interacting with each bowl
- Time needed for breaks between trials
- Optimal bowl and camera placement (if slip mats or fixed placements were needed for bowls, how many cameras were needed and the best locations)
- Whether dogs remained motivated throughout the allocated trial time
- Signs of anxiety, fear or fatigue before all trials could be completed
- Duration of a complete test session
- What behavioural and interaction indicators should be used for the ethogram

Pilot data were not included in the final analyses.

Test Day

Each test day consisted of six trials, one for each possible colour combination of the bowls. A randomised combination order was used for each dog through random selection of ordering done prior to the dog's arrival.

Table 2. All possible colour combinations for the three coloured bowls presented during each trial. Each test had all six combinations presented in a randomised order.

Combination	Colours		
1	Red	Yellow	Blue
2	Yellow	Red	Blue
3	Red	Blue	Yellow
4	Blue	Yellow	Red
5	Yellow	Blue	Red
6	Blue	Red	Yellow

Between each trial, the dog returned to the waiting area with their owner for a maximum of five minutes. During this time, the testing room was cleaned of any leftover food or excretions, and new food was placed in the same bowls (no deep cleaning was performed between trials for the same dog). Owners could bring toys or blankets to help their dog relax between trials. Water was available at all times, but no food or treats were allowed between trials.

Each dog had their own set of bowls that were thoroughly cleaned and dried between test days to minimise scents. The testing and waiting rooms were also swept and cleaned using disinfectant to minimise any residual odour and traces of the other subjects between dogs.

Description of a Trial

Before each trial, the dog's usual food (brought by the owner) was weighed, and equal portions were distributed into bowls. Each bowl contained approximately 5.55% of the dog's meal, with the total amount divided evenly across 18 bowls in six trials.

The bowls were arranged in a line visible from the doorway, spaced evenly apart, and at an equal distance from the centre of the doorway, in pre-marked locations. The camera system was checked, and once recording began, the dog was brought to the entrance of the test room by the owner, who either opened the door and allowed the dog to enter immediately or gave a command for the dog to approach the food (if this was part of their usual feeding regime). The door was closed once the dog entered the room.

Based on the pilot studies, a trial duration of 1.5 minutes was selected. During this time, the dog's behaviour was recorded via cameras in the room and was observed manually from a live feed in the waiting room. Owners observed the session and could ask for their dog to be removed and the trials to be terminated at any time if they had any concerns. The dog remained in the room for the full 1.5 minutes unless they began showing signs of anxiety and/or a strong desire to exit the room, such as vocalisation, scratching at the door, pacing, or constantly revisiting and waiting at the door, with no interest in the food. If the dogs had to be removed before the full time was up, but they had interacted with all the bowls, the data was included, and that trial was

not repeated. Once the time had elapsed or all food had been consumed and the dog was showing signs of anxiety or desire to leave the room, the owner opened the door and called the dog back into the waiting room. The owner and dog then exited and waited in the designated waiting area while the room was set up for the next trial.

2.5 Main Study

Each dog completed three test days, consisting of six trials, with a maximum of 7 days between sessions. Testing was performed at approximately the same time of day for each dog to control the lighting conditions that may affect colour saturation.

Dogs were fasted for 6–8 hours before their arrival to enhance their food motivation during testing. Owners were responsible for transporting their dog to Massey. Upon arrival, the dog and owner were met by the researcher and accompanied to the research laboratory using either stairs or an elevator, depending on the dog's preference as indicated during habituation. Dogs entered the waiting area with their owners and were given a maximum of 10 minutes to acclimatise to the environment, during which time they were assessed by the researcher and supervisors, using the FAS scale to monitor their anxiety. If during this time, there were no concerns about their health or welfare, the dog was left in the waiting room with their owner while their food was weighed and allocated into portions for testing.

The test day and trial procedure described in the pilot study were then followed for all trials in the main study.

2.6 Data Analysis

Variables Measured

Videos were scored using Behavioural Observation Research Interactive Software (BORIS) (Friard & Gamba, 2016) with a standard ethogram used to score behaviours (Table 3). Manual notes made during live observations were used as a backup in case of recording failure. From the behaviour data, preferences were determined at both the individual dog and study population level.

Table 3. The behavioural variables measured from videos and/or live observation for each dog in each trial and used to create an ethogram to score and analyse each video using BORIS. The interactions were defined by the behavioural definitions.

Behaviours Measured	Behaviour Definitions
First bowl visited (categorical)	First bowl that the dog approached and interacted with by either touching the bowl with their nose or lowering it inside the bowl.
Number of visits to bowl (continuous)	Number of times the dog revisited and touched the bowl with their nose or lowered it inside of the bowl. It was only counted as a new visit if they have turned and walked away before returning.
Latency to reach bowl	The time it took the dog to reach each of the bowls at the start of every trial from the moment they entered the room, and the door was closed behind them.
Percentage time spent interacting with each bowl (continuous)	Total percentage of time spent with each bowl for each trial. The percentage was divided from the time the individual spent in the room; from the moment they entered, and the door was closed behind them, until the door was opened again and their owner called them out.
Duration of visit to bowl (continuous)	Total time (seconds) the dog spent interacting with each coloured bowl. An interaction was considered if the dog touched the bowl with their nose or lowered it inside of the bowl. All interactions for each bowl were added together for a total time spent with each colour in that trial.
Latency to visit the first bowl in each trial (continuous)	The time it took for the dog to reach the first bowl chosen at the start of every trial, from the moment they entered the room, and the door was closed behind them.

Statistical Analyses

All statistical analyses were carried out in SAS version 9.4 (SAS Institute Inc, 2025)

Categorical data: First bowl visited in each trial

Data for all dogs combined were analysed using a Chi-square test. Analyses were conducted both across all testing days combined and separately for each testing day. For individual dogs, the counts for specific categories were too small to meet the assumptions of the Chi-square test; in these cases, Fisher's exact test was used. For individual dogs, analyses were only conducted using the combined data from all three testing days (n=18 trials).

Count and continuous data

The distribution of the residuals was evaluated, and a transformation was attempted to improve the distribution before analysis. For all tests, significant effects were accepted when $P = <0.05$, and tendencies when $0.05<P<0.10$. When a main or interaction effect was found, post-hoc tests were conducted with a Bonferroni adjustment for multiple comparisons.

Count data: Number of visits to the bowl

Neither log transformation nor ranking improved the distribution for these count data. Therefore, raw counts were analysed using Poisson regression (PROC GENMOD). 'Dog' was included using a generalised estimating equation to account for repeated measurements on the same individual. Including the interaction between colour and location did not improve the fit of the model, so the final model included only the main effects of bowl colour and location.

To examine individual-level preferences, Poisson regression was conducted with dog included as a fixed effect along with bowl colour and location. Second-order (dog*colour, dog*location, colour*location) and third-order (dog*colour*location) effects were retained if they were significant or improved the fit of the model.

Continuous data: Latency to reach bowl, percentage of time spent interacting with bowl, average duration of visits to bowl, and latency to reach bowl first visited

Log transformation improved the distribution of the residuals for all continuous variables. To evaluate population-level responses, log-transformed data were analysed using repeated measures ANOVA (PROC MIXED in SAS). 'Dog' was included in the models as a repeated measure to test for the main effects of bowl colour and location. The second-order interaction (colour*location) was retained if it was significant or when it improved the fit of the model using Akaike's criterion.

To examine individual-level preferences, separate analyses were conducted using ANOVA with dog included as a fixed effect along with bowl colour and location. Second-order (dog*colour, dog*location, colour*location) and third-order (dog*colour*location) effects were retained if they were significant or improved the fit of the model.

3. Results

3.1 Effect of Colour

3.1.1 Population Level

At the population level, there was no significant effect of bowl colour on the first bowl chosen by dogs in each trial: Red was chosen first in 42% of trials, Yellow in 31% and Blue in 28% (χ^2 (2) = 4.03, p = 0.13). Nor did colour have any effect on first choice on any individual test day, with a tendency to choose red on only the first day: Day 1: χ^2 (2) = 4.82, p = 0.09; Day 2: χ^2 (2) = 0.70, p = 0.70; Day 3: χ^2 (2) = 0.28, p = 0.87.

Colour did influence dogs' latency to approach the bowls (F(2, 24) = 5.96, p = 0.008). Specifically, dogs approached the red bowl significantly faster than the blue (t = 3.06, p = 0.02) and yellow (t = 2.91, p = 0.02) bowls (Figure 11). There was no difference in latency to reach the blue and yellow bowls (t = 0.15, p = 1.00). However, latency to reach each colour bowl when it was chosen first in a trial did not differ between colours, and bowl colour did not affect any other behaviour at the population level (Table 4).

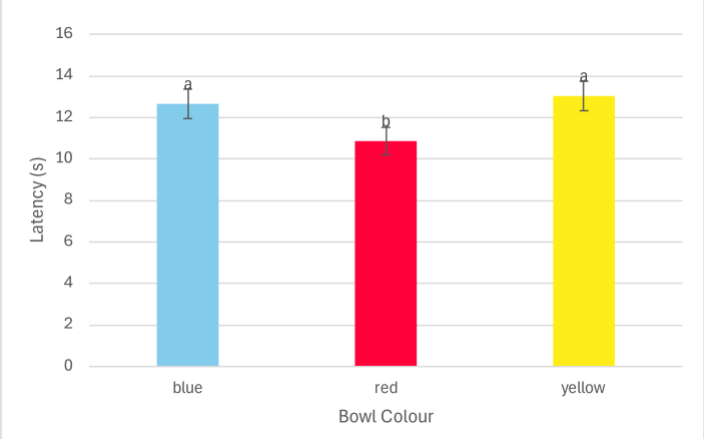

Figure 11. Mean (± SE) latency of dogs (seconds) to reach each bowl colour during a trial for 13 dogs in 18 trials over 3 test days. Columns with different superscript letters are significantly different.

Table 4. Results of repeated measures ANOVA (or Poisson regression) for evaluating population-level preference for colour or location among 13 dogs. Mean and standard error for each colour or location are presented.

	Colour					Location				
Variable	Red	Yellow	Blue	F (2,24)	P	Right	Middle	Left	F (2,24)	P
Latency to first visit bowl (s)*	2.96 ± 0.15	3.53 ± 0.33	4.30 ± 0.91	2.45	0.11	3.87 ± 0.46	2.92 ± 0.24	3.06 ± 0.20	1.65	0.22
Average duration of visits (s)	9.03 ± 0.34	9.28 ± 0.36	8.63 ± 0.32	1.06	0.40	9.53 ± 0.34	7.96 ± 0.28	9.45 ± 0.38	6.4	0.0059
% Time interacting	11.99 ± 0.40	12.14 ± 0.41	11.45 ± 0.36	0.96	0.40	12.54 ± 0.37	10.47 ± 0.30	12.57 ± 0.46	9.50	0.0009
Number of visits to each bowl**	1.52 ± 0.04	1.49 ± 0.04	1.52 ± 0.04	0.80	0.67	1.46 ± 0.04	1.56 ± 0.05	1.50 ± 0.04	1.40	0.50

**Location df= (2,18). Bowl colour chosen first: Red (n=98), Yellow (n=73), Blue (n=63). Location chosen first: Right (n=135), Middle (n=51), Left (n=48).*
*** Counts data, test statistic X^2(df=2)*

3.1.2 Individual Level

The proportion of trials in which each bowl colour was chosen first was not significantly different from chance for any individual dog (Fisher's Exact tests, all p = >0.05). Some dogs tended to choose red first in more trials than expected: Billie 61%, Bowie 72%, Coigley 61% (Fisher's exact tests 0.05<p<0.1). On day one, Coigley chose the red bowl first in all six trials.

There was a significant interaction effect of dog and colour on latency to reach each bowl (Table 5); the effect of colour on latency varied among dogs. Billie approached the red bowl significantly faster than the blue bowl (adjusted p-values < 0.05). Bowie also approached the red bowl significantly faster than the blue or yellow bowls. None of the other 11 dogs showed significant differences in latency to approach the red, yellow, or blue bowls.

Table 5. Results of ANOVA for evaluating individual-level preference for bowl colour or location on latency to reach each bowl among 13 dogs.

Effect	DF	F	P
Dog	12, 633	17.74	<0.0001
Colour	2, 633	11.47	<0.0001
Location	2, 633	59.34	<0.0001
Dog*Colour	24, 633	2.21	0.0009
Dog*Location	24, 633	18.18	<0.0001
Colour*Location	4, 633	1.6	0.174

In contrast, there was no interactive effect of dog and the bowl colour chosen first in each trial on the latency to reach that bowl ($F(24, 175) = 0.73$, $p = 0.82$). There was significant variation among individuals for the percentage of time spent interacting with bowls ($F(12,685) = 30.40$, $p < 0.0001$), and the average duration of visits ($F(12,685) = 61.21$, $p = < 0.0001$), but there were no significant colour differences (Percentage time = ($F(2,685) = 1.44$, $p = 0.238$), duration time = ($F(2,685) = 2.15$, $p = 0.117$)).

The number of visits to each bowl also varied across dogs (χ^2 (12) = 43.34, p = < 0.0001). Bowie (2.03 ± 0.09) visited each bowl more often than Cino (1.16 ± 0.05), Lilo (1.06 ± 0.03) and Rosie (1.06 ± 0.03). Whereas Coigley (1.83 ± 0.11) tended to visit each bowl more often than Lilo and Rosie. However, there was no significant colour effect (χ^2 (2) = 0.11, p = 0.948).

3.2. Effect of Location

3.2.1 Population Level

At the population level, there was a significant effect of location on the first bowl chosen in each trial ($X^2(2) = 28.05$, $p = < 0.0001$), with the bowl in the right location being chosen first in a greater proportion of trials than the bowls in the middle or left location. The bowl in the right location was also chosen first in significantly more trials than the bowl located in the middle or left on test day one ($X^2(2) = 9.53$ $p = < 0.009$), day two ($X^2(2) = 9.01$ $p = 0.011$) and day three ($X^2(2) = 13.71$ $p = < 0.001$) (Figure 12).

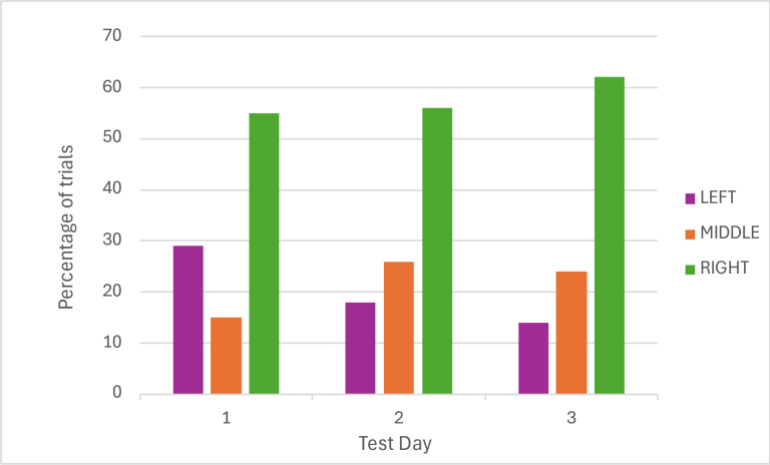

Figure 12. Percentage of trials in which the bowl in the right, middle and left location was chosen first by 13 dogs in 6 trials on each of three test days.

There was a significant effect of location on dogs' latency to reach each bowl during the trials ($F(2,24) = 30.83$, $p = <.0001$). At the population level, dogs approached the bowl in the right location faster than the bowl on the left ($t = 7.83$, $p < 0.0001$) and the bowl in the middle ($t = 4.42$, $p = 0.0006$) (Figure 13). There was also a significant difference between the left and middle locations, with dogs approaching the bowl in the middle faster than the bowl on the left ($t = 3.42$, $p = 0.007$).

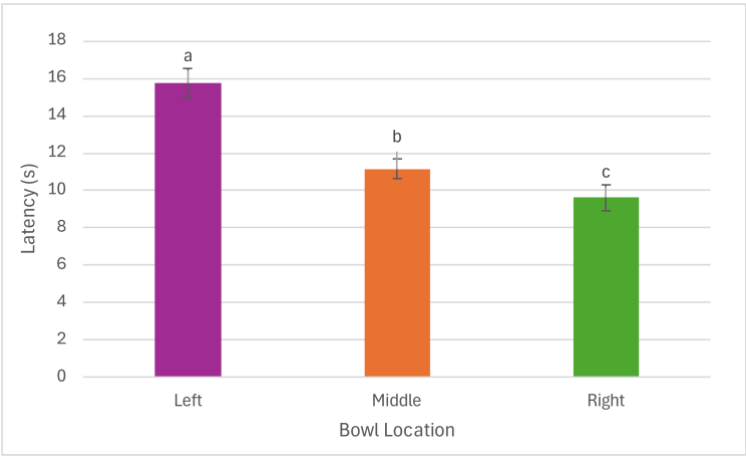

Figure 13. Mean ± SE latency (seconds) of dogs to reach the bowl in each location for 13 dogs in 18 trials over 3 test days. Columns with different superscript letters are significantly different.

There was also a significant effect of location on the percentage of each trial spent interacting with the bowls and the average duration of visits to each bowl (Table 4). Dogs spent less of the

trial interacting with the bowl in the middle location and made significantly shorter visits there compared to the left or right.

3.2.2 Individual Level

The proportion of trials in which each bowl location was chosen first was significantly different from chance for six of the 13 dogs ($X^2(2) = 28.05$, $p = < 0.0001$). Five dogs (Pixel, Rosie, Inky, Lilo and Daisy) chose the bowl in the right location first in more trials than they chose bowls in the other locations first (Fisher's Exact test, $p = <0.0001$). Cino chose the bowl in the left location first in more trials than bowls in any other location ($p = 0.013$).

The effect of location on latency to visit the first bowl in each trial varied among dogs (Table 4). Six dogs (Daisy, Inky, Lilo, Moss, Pixel and Rosie) reached the right location most quickly, three dogs (Cino, Bowie and Zero) reached the left location quicker than one or both of the other locations, and three dogs did not differ in time to reach the different locations (Billie, Sally and Tui). Coigley reached the middle more quickly than the right.

Dogs also varied in their latency to approach the first bowl chosen in each trial ($F(12,175) = 9.08$, $p = < 0.0001$); Pixel, Rosie, and Tui took significantly longer to reach the first bowl compared to Billie, Bowie, Coigley, Daisy, Inky, Lilo, Moss, Sally, and Zero (all adjusted $p < 0.05$). Billie reached the first bowl more quickly than Cino and Sally, while Cino took longer than Bowie, Coigley, and Lilo. There was no interaction between dog and first location chosen ($F(18, 175) = 1.44$, $p = 0.12$).

There was a significant effect of dog ($F = 30.40$ (12,685) $p = <0.0001$) and of location ($F = 14.31$ (2,685) $p = <0.0001$) on the percentage of time spent with each bowl, but no significant interaction between dog and location. The duration of visit to each bowl was also significantly different between dogs ($F = 61.21$ (12, 685) $p = <0.0001$) and the bowl location ($F = 13.03$ (2,685) $p = <0.0001$), but there was no significant interaction between dog and location. There was no significant difference between the number of visits to each bowl and location ($\chi^2(2) = 0.75$, $p = 0.686$).

4.0 Discussion

4.1 Key Findings

This study aimed to investigate whether dogs displayed a colour preference when presented with different coloured stimuli in a free-choice preference test. Overall, the results did not provide strong evidence of a colour preference at an individual or population level. While dogs approached the red bowl more quickly than the other colours, there was no statistically significant difference from chance in the number of trials in which the red bowl was chosen first. Nor did the number of visits, overall time spent with the bowl, or average visit duration differ according to bowl colour. However, the latency to reach the red bowl the fastest is most likely because red was chosen first in the most trials overall (41%). There was no indication of a colour preference on test day two or three; however, there was a tendency to pick red the most on test day one ($p = 0.09$).

At the individual level, two of the 13 dogs tended to choose red first more often than expected by chance overall (Billie $p = 0.08$ and Bowie $p = 0.09$), choosing this colour first in over 60% of the trials. In addition, Billie and Bowie both approached the red bowl significantly faster than the other colours. For some dogs, this tendency to prefer red was evident on the first test day. For example, Coigley picked the red bowl first in all six trials ($p = 0.06$) (Appendix C). However, the number of trials was too small for these results to show a statistically significant difference from chance on day 1 or overall. This is evident with other dogs such as Bowie, who picked red first in five out of six trials ($p = 0.11$).

The individual analyses also indicated that no dog showed any preference for blue or yellow overall. Five of the 13 dogs did not indicate any preferred colour at all, and chose all colours equally (Daisy, Rosie, Pixel, Lilo, Inky, $p = 0.99$), likely because they based their decision on location, and the colour rotated to that location every 3rd trial.

4.2 Possible Explanations for the Lack of Significant Colour Preference

4.2.1 Colour May Not Be Meaningful to Dogs

It is possible that dogs did not demonstrate a significant preference for colour because it is simply not very meaningful to their decision-making. Dogs have dichromatic vision, with cone

photoreceptors sensitive to wavelengths at 429 nm (blue) and 555 nm (yellow), but the lack of a long cone receptor means they cannot absorb longer light wavelengths such as those that respond to the colour red (Miller & Murphy, 1995). As a result, dogs instead perceive red as a dark yellow/brown hue, and they cannot easily distinguish between these different colours. Thus, while humans with normal vision generally can easily discriminate between red, yellow, and blue contrast, dogs perceive things more similar to humans with red-green colour blindness, with mostly different shades of brown or grey outside of their saturated peaks of blue and yellow. Although we know dogs can discriminate between some colours, and prior studies have shown they prefer yellow (Boonhoh et al., 2024; Roy et al., 2024), colour may not matter to them as much as other sensory modalities. Previous studies investigating canine colour vision have shown various results. For example, it was found that dogs relied more on the contrast of colour than brightness, and could easily discriminate between yellow and blue, but found it more difficult to distinguish red compared to darker colours (Kasparson et al., 2013). Whereas a study investigating colour discrimination in dogs found that varying levels of brightness affected their ability to discriminate between colours, and they relied on input from both photoreceptors for sensory information and visual input (Byosiere et al., 2019). These results suggest that while dogs can perceive colours, it is not particularly useful for them on its own, but rather is generally used simultaneously with other sensory modalities for perception. Although it may be useful for enhanced detection in varying light conditions, colour alone may not be a significant tool compared to other sensory processes, and it is not something they have evolved to inherently rely on.

There are many anecdotal claims that because dogs can see blue and yellow best, they prefer these colours (Anonymous, 2024; Basepaws, 2024). The small amount of scientific research on this topic has only explored preferences between blue and yellow, with no other colours presented for comparison (Boonhoh et al., 2024; Roy et al., 2024). These studies indicated that dogs did have a population-level preference for yellow over blue. The weak tendency for red that was observed in this study did not correspond with what we expected based on the knowledge and previous studies we have about dogs' colour vision, as this is not easily distinguishable for them compared to blue or yellow. The difference in these findings may be caused by the methodology differences and statistical analysis. Both previous studies only determined

preference at a population level and did not study any individual differences. In contrast, the current study assessed each dog repeatedly across multiple test days and considered both individual and population-level outcomes.

The study using free-range Indian dogs (Roy et al., 2024) had a large population varying in locations and tested only once each in their home location, with the option of yellow, blue, or grey. Similarly, the study using rubber toys (Boonhoh et al., 2024) tested a small sample of dogs in their home environment and assessed preference between the choice of yellow or blue. Both these studies determined 'preference' only by which stimulus was approached or interacted with first; neither considered other behavioural factors, nor retested any of the subjects to see if their results changed over multiple days.

In this study, the first choice was measured; however, other behavioural variables were included, such as latency to reach the bowl (both overall and to the first bowl only), the number of visits, the total percentage of time spent, and the average duration of visits. Incorporating these variables provided a more in-depth analysis of dogs' responses to colour. The results indicated there was a significant difference between latency to reach the bowl and colour, with an overall faster approach to the red coloured bowl. Similarly, there was a weak preference between colour and first bowl visited, with red being chosen the most. However, the other variables measured did not consistently support these findings, with no indication of any preference between colour and the behaviours measured. There was also a stronger tendency to approach the red bowl first on the first test day; however, when dogs were retested, these findings got weaker every day, showing no indication of any colour preference on day three. This was also prominent in some individual dogs, such as Coigley, who at first had strong colour choice, but over time and repeated trials, started to choose based on either random choice or side preference.

Thus, only measuring the first choice and only one test per dog may not be enough information to indicate if their choice is a true preference, and these previous studies may have drawn conclusions without enough evidence based on the behaviours measured. The individual dog results from this study also showed significant variability between interactions, such as latency and time spent with each bowl. Only a few of the 13 dogs included showed any tendency to

favour a colour, which may explain the variability and differences within the population, which should be considered when investigating preference for a species. By grouping all dogs together, it is difficult to understand how varying personal behaviours may contribute towards their decision, and what actually may be best for individuals who don't follow the same choice pattern as others.

Alternatively, the lack of colour preference may be because the dogs could not differentiate between the colours clearly. Dogs are known to rely on movement for spatial awareness and tracking (Lõoke et al., 2020). Dogs reactions are based on their ecological drive, reacting to moving objects, as in the wild, they need to do so to catch food (Barber et al., 2020). The ability to discriminate between colours is beneficial for survival by creating more contrast in their environment, which, when paired with enhanced light sensitivity and motion detection, helps dogs perceive depth and improves their ability to track and hunt (Neitz et al., 1989). The stimuli in this study were stationary and presented in a controlled, barren environment, with artificial lighting. Thus, dogs' ability to detect and discriminate between the different colours may have been limited. These factors, along with bowl placement relative to the dogs' line of vision (see section 4.3.1 below), may have reduced their ability to differentiate clearly between the colours.

Using stimuli designed to match dogs' peak colour sensitivity could have enhanced their colour discrimination. The stimuli in this study were chosen to approximate the colour wavelengths that dogs are most sensitive to, but budget and availability restrictions limited the ability to design specific stimuli, and the bowls may not have completely matched their most sensitive wavelength peak. Designing stimuli with a spectrometer to match the colours that are most saturated for dogs would be beneficial, as it may alter their preferences if we knew exactly what hues and colour saturation they were presented with, not just a comparison of how we perceive them.

Lighting and contrast in the test environment should also be considered, as colour discrimination varies depending on luminance level and whether it is presented against other coloured backgrounds (Byosiere et al., 2019; Kasparson et al., 2013). Therefore, to achieve the most accurate colour discrimination among stimuli, the experiment could be repeated using colours at

their peak sensitivity, presented with an achromatic background and controlled lighting. This would help reduce the chance that a lack of preference was caused by an inability to distinguish colours clearly.

Finally, it is possible that any weak colour bias was overshadowed by location preference. The stronger tendency to choose red on day one may reflect a choice based on curiosity or chance, but over numerous days, many dogs appeared to make a decision based on location, which overruled any colour preference (Appendix C). Furthermore, because all bowls remained available after the first choice, they were able to revisit all the bowls as many times as they liked, with no cost for their choice associated with the initial selection. The results might have been different if the dog had only been able to access the bowl first chosen.

4.2.2 Location Preference

The results indicated there was a preference for the location of the bowls at both the population and individual level for some dogs. Six of 13 dogs chose one location more often than expected. Five preferred the right location, and one (Cino) had a significant preference for the left location. These location biases appeared to outweigh or dilute any influence of colour preference on dogs' behaviour, particularly in the later testing days, as evident from the chi-square results for the first location chosen overall which on day one of testing resulted in a preference ($p = 0.009$), but this increased by day 3 with a stronger location bias ($p = 0.001$).

Overall, only 6/13 showed statistically significant location biases; however, two other dogs showed a tendency to prefer one location more than the others. Based on the first choice, Moss tended to approach the right location first the most, whereas Coigley tended to approach the middle the most, and was the only dog in the study to show this pattern.

There was no significant effect of location on the number of visits to each bowl. However, dogs spent less time and a smaller proportion of time interacting with the middle location compared to the left or right, with no significant difference between the left and right locations.
Overall, dogs approached the right bowl the fastest, and there was a significant difference between individual dogs and their latency to reach each location ($p = <0.0001$). These

behavioural interactions reinforce the main finding that there was an overall preference for the right location compared to the left or middle. This was observed in almost half the individual dogs, with only a few individuals preferring other locations or having no location preference at all.

This finding indicates that any colour preference was not sufficiently meaningful to determine dogs' decisions. Instead, location appeared to have a stronger influence on their decisions.
The general preference for the right location may be because of how the bowls were presented. When entering the room, the right bowl was the first to be seen, which could have influenced the initial choices, even though it was no closer to the door than the other bowls, so it was not actually any more cost-effective to choose this location first. Repetitive trials most likely solidified this pattern in many dogs, strengthening this side bias into a habitual behaviour.

Y-maze preference tests have commonly been used to study farm animals, and many studies have shown that they often exhibit 'side preference', repeatedly selecting the same side over multiple trials (Anderson & Murray, 2013; Doyle, 2017; Langbein, 2018).
In this study, the right bowl was no closer to the door than the other bowls, so it was not the most cost-effective choice; it was just the first bowl visible when the door opened. The preference for the right location may be because of the brain and sensory lateralisation. Brain laterisation refers to how the left and right sides of the brain have specialised attention to different information, and process sensory inputs differently to control various motor behaviours (Rogers, 2021). This lateralisation is known to influence decision-making and motor patterns in vertebrates such as dogs.

For instance, dogs were studied to exhibit paw preferences and how this was linked to their motor control system and problem-solving behaviour (Siniscalchi et al., 2017). There was a correlation found between the paw preference and other traits such as social behaviour, emotional responses, and visuospatial processing. Dogs that had a weaker paw preference tended to be more emotional and worse at solving tasks, particularly when their owner was visible in their left visual field, forming an emotional response as a result of the right hemisphere being activated.

Similar studies regarding dogs' cognition have also associated lateralisation with emotional and sensory processing (Simon et al., 2024). Dogs' eye use and tail wagging patterns were investigated when presented with food or toys to indicate the influence on lateral positioning and behavioural responses. This data indicated that when presented with food, overall, the dogs were dominant with their right eye, linked to the engagement of the left hemisphere. This highlights that inherent lateral bias may influence location preference and result in one side being constantly chosen more than the others, particularly if individuals have more of an emotional response or external factors influence how they perceive the stimuli. This may operate independently of any cost-effect or task efficiency, which would explain why the right side was favoured even though it was actually not any closer than the middle or left bowls.

When presented with a two-choice maze, rodents often display 'spontaneous alternation behaviour', switching from side to side in subsequent tests (Deacon & Rawlins, 2006; Kim et al., 2023). No clear evidence of such behaviour was observed in any of the subjects of this study. The prominence of location preference from the first trial of each testing day suggests that the side bias was already present in most dogs from the beginning. Some dogs did change locations at least once, with Rosie being the only dog to choose one side 100% overall; however, this was usually random and not at the start of the first trial or in any recurring patterns, indicating that the preference was not solely the result of repeated exposure.

The dogs that had no location preference, such as Billie and Bowie, did tend to pick the red coloured bowl more than the yellow or blue. Similarly, Coigley, who tended to pick red the most on day one, had a weaker preference for location overall. Thus, location may not have been as important to these individuals, or their choice of both colour and location was completely random with no preference for either variable. More testing would be required to further investigate these differences and any patterns that may occur if more data were collected.

4.3 Methodological Considerations

4.3.1 Presentation of Colour

The way colour was presented may have influenced dogs' perception and thus, behaviour. The bowls were coloured only on the outer vertical surface and uniform stainless steel on the top and inner surfaces. If the colour had been on the inside where the food was, we may have observed a difference, as it could be more directly in their field of vision as they approached the bowls and stand out more.

The bowls were placed on the floor, visible to the dogs when they entered through the doorway. The average latency to reach the first bowl in each trial ranged from only 3 seconds (red) to 4.3 seconds (blue). Some dogs were slower than others, such as Pixel, who was significantly slower than most dogs over all three days, but most dogs were consistent with their latency to approach. This indicated that dogs tended to make their decision at the doorway from the moment they entered the room, but they may have noticed the food within each bowl first, focusing on the reward rather than acknowledging the outer colour of each bowl the food was in.

In contrast, the miniature schnauzer (Coigley) likely saw the bowls themselves before noticing the food in them due to the horizontal field at his height. This may be why on the first trial day, Coigley seemed to pick based on colour, choosing the red bowl first 100%. Similarly, the Staffordshire terrier (Moss) picked the same colour more consistently on the first day of testing, choosing the red bowl almost 70%. This was then overruled by side preference for days two and three. However, the initial consistency for colour choice compared to some larger breeds may be because they noticed the colour first, rather than just the food inside.

4.3.2 Test Environment

The testing room was kept bare to minimise external distractions and ensure consistency across all dogs. It is possible that this relatively unfamiliar environment could have heightened feelings of anxiety in some dogs during the trials when left alone, potentially influencing their behaviour and preferences. Novel and barren settings can increase stress levels (Rooney et al., 2007), which may impair animals' decision-making and preferences (Chabout et al., 2013).

To reduce this effect, multiple habituation sessions were conducted for each dog before testing. Some dogs took notably longer to adjust and required multiple sessions before showing fewer signs of fear and anxiety in the room. Although the dogs were only alone for brief periods, with a maximum of 1.5 minutes in the room, and they were not allowed to participate if they scored more than a one on the Fear and Anxiety scale, the test environment could still have impacted their interaction with the stimuli and expression of any colour preference. Some dogs, such as Cino and Daisy, that were more fearful than others during habituation, could not stay for the full 1.5 minutes during the trials as they began to show increased anxiety. Similarly, we had to adjust the approach of testing for some anxious dogs, such as Billie, who required extra encouragement and time playing before each trial so she would want to participate and would interact with each bowl. The dogs were all fasted for 6-8 hours before their testing to increase their hunger motivation; however, it was notable that dogs that were more uncertain about the environment tended not to finish all their food and would prefer to wait at the door to be let out to their owner than spend more time interacting with the stimuli.

Fear and anxiety can increase perseverative behaviour, such as the persistence of side biases (Burman et al., 2009), reducing responsiveness to sensory cues like colour, and instead basing decisions on habitual or random choice patterns. Cognitive bias has been studied in animal welfare through their decision-making, and how this relates to the emotional state (Mendl et al., 2009). Many of these studies have found that when animals are tested in a barren or novel environment, they exhibit increased emotions and make choices based on these feelings and induced judgment bias (Baciadonna & McElligott, 2015; Roelofs et al., 2016). Thus, some dogs, particularly those that had more trouble during habituation, may still have been influenced by their emotions.

Presenting stimuli in a familiar environment may reduce anxiety; however, it could compromise the control over external factors, potentially introducing more distractions, interfering with the trials and making it difficult for consistency across all dogs to be maintained.

4.3.3 Preference Testing Method

The use of a free choice preference test was the most logical to achieve the aim of this study, which was to compare more than two stimuli and not needing to train the subjects beforehand. This method allowed the dogs to move freely between options, enabling us to measure not only which bowl was approached first, but also the duration of interaction, the number of revisits, and patterns of exploration.

If a fixed-choice preference test had been used, the dogs would have had to learn the location of the bowls before testing, and their decision in the test could have been influenced by their ability to learn the bowl positions rather than by a true colour preference. This method could also introduce side bias, as some dogs may rely more heavily on their spatial memory than on visual cues when making a choice, confounding the results by reflecting differences in learning or problem-solving strategies rather than a genuine preference for one colour over another (Kis et al., 2025).

A fixed-choice preference test also takes longer because of the time required to train all the dogs before testing. Because there were three stimuli in this study, a Y-maze or T-maze could only have been used to present two of the stimuli at a time, requiring multiple tests to compare all three stimuli and transitive inference to determine an overall preference.

It would be interesting to see if presenting the same stimuli in a fixed choice preference test would result in the same choice of colour preference or location bias. It is likely, given that dogs showed a significant preference for the right side, that if a similar room layout was presented, but segregated into separate pathways instead of open access to perform a fixed choice test, over time, we would see the same behaviour of location bias.

As well as recording which coloured bowl was approached first in each trial, we also wanted to observe different types of behaviours dogs expressed to understand any manifestation of a colour preference better. In a fixed-choice test, the subject can only choose once, and preference is based only on this choice. This is beneficial in many research areas because it forces one clear choice and adds a ‘cost’ as they don’t get to choose again if the one picked is not what they

preferred the most, whereas there is no cost to a free choice test, where they can revisit as many times as they like (Dawkins, 1977). It is also easier to identify a clear marker of preference based on the number of times the same choice is made, and considering a preference if they pick the same side a certain number of times overall (d'Isa et al., 2021); however, it reduces the opportunity to examine repeated interactions or subtle differences in how the stimuli are interacted with.

A key reason for testing dogs' colour preference was so that the information gained could be incorporated into the design of enrichment tools in their environment. This meant that it was beneficial to understand how they interacted with the stimuli and the frequency with which they did so. This information can be taken into consideration to improve dog welfare by promoting interactions and play behaviours. Because we used food as a motivator, there were no play interactions; however, the time spent, number of revisits, and duration spent were all analysed as useful interactions for understanding how the dog reacted to each coloured stimulus, and the use of a free choice preference test meant that this data could be recorded through free movement among the stimuli.

Overall, the use of a free-choice preference test in this study influenced the results by allowing us to capture a wider range of behaviours beyond simple first choice. This provided insights into how dogs interacted with the stimuli over time, which was beneficial for the aim of this study; however, it was also limited by the prominent location bias, which must be considered when interpreting the findings and could be minimised through other preference testing methods.

4.3.4 Owner's Influence

The body language and gestures of the owners between trials and when asking them to enter the room at the beginning of each trial may have also unknowingly influenced the dogs' choices. We generally are not aware of it, but we are constantly providing signals to dogs, and they react to even the slightest changes in our behaviour (Ishikawa et al., 2018). Domestic dogs have particularly become susceptible to reading their humans' body language and detecting any emotional or behavioural cues (Huber et al., 2023).

For each trial, the owner was asked to open the door for their dog to enter the testing room. This was hard to keep consistent as different dogs required different cues; some needed to be encouraged to enter the room, some had certain word commands so they knew it was okay to eat, and others had to be told to sit and wait at the door before entering because they were overly excited and would try entering before the door was properly opened. Through all of these interactions, the subjects were likely picking up on their owners' body language, which may have unintendedly affected what bowl they chose first (Prato-Previde et al., 2008). In particular, the way the owners opened the testing room door could have affected the dog's first choice by where they stood, how they gestured for the dog to enter, how wide they opened the door for the dog, and if they were blocking any of their view to the bowls when they first entered. Some of the very excited dogs would start to enter the room before the door was fully open, and the owner was still standing half in the room, either standing facing the room or sideways, which may unknowingly direct the dog in the same direction.

In future trials, it may work better to have only one person opening the door and interacting with all the dogs when they are getting ready to enter the test room. However, we chose not to do this for this study and had only the owners handling their dogs to minimise any anxiety the dog may have had when interacting with a stranger. Some of the dogs involved in this trial noted in the questionnaire that they were not comfortable with new people, and this may have caused unnecessary increased anxiety before and during testing.

We considered whether some dogs relied on their owner before making a first choice, based on their "biddability" - the willingness and responsiveness to follow human direction (Dictionary, 2024). Previous research indicates that certain breeds, particularly those bred for functional working roles, tend to be more sensitive to human communicative cues than other dogs bred as companions (Dobos & Pongrácz, 2024; Wobber et al., 2009). Working breeds are trained to respond and act based on their owners' cues; thus, their decision-making is generally affected by what they think is being asked of them (McCartney & Leavens, 2024). Videos were reviewed for signs of 'biddable' behaviour such as looking back at the owner, as dogs are known to communicate with humans through their gaze, reading subtle cues such as head turning or glances to understand what is being asked of them (Bray et al., 2021; Miklosi et al., 1998). We

categorised dogs as being biddable if there was a pattern of turning or looking back at their owner at the start of each trial before the door was closed behind them. Although some dogs did look back at their owner in some trials, this behaviour was not consistently observed by any individuals. Thus, there was insufficient evidence to undertake a formal analysis to see whether biddability influenced behaviours reflective of colour or location preference. As this was not a primary objective of this study, no further investigation was taken.

4.3.5 Breed Differences

Different dog breeds also tend to differ in their behaviour (MacLean et al., 2019). In this study, dogs of working breeds or crossed with working breeds, such as NZ Huntaway or Border Collie, seemed to choose a particular side more frequently than any colour choice. For example, Rosie, a working Huntaway X, consistently chose the right side and was the only individual to pick the same location in all trials. Similarly, Pixel (pure Border Collie), Lilo (Huntaway cross), and Daisy (Huntaway × Border Collie) showed notable side bias, all choosing the right side over 90% first overall. Previous research has shown that working breeds tend to have higher trainability and a stronger drive, often focusing more on cues and patterns (Lord et al., 2016; Turcsán et al., 2011).

These observations suggest that the genetic background may predispose different breeds to prioritise different preferences, such as location over colour. Although there is not enough data to confidently say the behaviour shown in these specific breeds was not just a pure coincidence, it is worth noting as something to investigate in future studies.

4.3.6 Previous Experience and Learning

It is possible that the expression of a colour preference could be influenced by associative learning, whereby repeated exposure to specific coloured objects during play, training, or feeding creates a positive emotional response to that colour (Kelber et al., 2003). Repeated exposure to a stimulus has been shown to lead to a generalised preference for a colour itself (Hurlbert & Ling, 2012). For example, the tendency for some individuals in this study to pick red more may be because they associate it with the different shades of brown or grey they see commonly in their environment, such as dog toys, treats and food in these hues. So, it is possible they associate the

reward of food with red/brown colours, and tend to be more attracted to this, but the preference for this was too weak for any clear correlation.

While associative learning remains a constant consideration when preference testing, the uniformity of colour choices observed in this study suggests that prior experiences did not strongly shape the results, and any tendency towards red seen in individuals may have been due to chance, or weak associations with red/ brown hues and their food or common environmental stimuli.

4.3.7 Sample Size

Finally, the small number of dogs used in this study may have limited the power of the analysis to detect a statistically significant effect of colour on behaviour at the population level. If more dogs had been recruited, the results may have been more representative of the wider population and allowed for more robust statistical comparisons.

The small number of trials per dog meant a Fisher's exact test had to be performed to determine the observed distribution of dogs' first choices relative to chance. This test is very conservative, as it is conditional on the total number of successes being fixed and calculates the exact probability rather than relying on an approximation like a chi-square test does. This generally results in a higher p-value and requires larger differences to reach any statistical significance (Crans & Shuster, 2008; Sauro & Lewis, 2012). Thus, even when one colour was chosen in 100% of the trials on a given test day, the difference was too small to detect and resulted in a larger p-value. If more trials were completed on every test day rather than just six, it would allow the use of more reliable statistical methods, such as the chi-square test, which can measure more variables and provide greater statistical power. It would also indicate if there actually was a preference for the red bowl for some dogs, or if this was just random.

4.4 Practical Implications of the Findings

Unlike previous studies (Boonhoh et al., 2024; Roy et al., 2024), this study found no strong evidence that dogs exhibit colour preferences when offered a choice between red, yellow, and

blue. From a practical perspective, this suggests that there is likely little benefit to enriching dogs' environments solely based on colour.

Humans probably care more about the colour of items used for 'dog enrichment' than the dogs themselves do, and marketing is aimed at owners rather than dogs (Dimtirova, 2021). This is evident in the little research done about dog colour preference, and that canine products are still designed in a variety of colours, many in hues that are not even visible in the dog's colour spectrum. This is because it is designed to appeal to the consumer, as humans are more likely to buy something appealing to them (Forbes, 2018; Gomez Baquero et al., 2018). Enrichment tools should be designed to encourage an animal's agency and promote their natural behaviour (Bender & Strong, 2019). There is no evidence that dogs care about the colour of their stimuli; however, many studies indicate that there is a preference for texture or scent, which should be focused on for enhancing enrichment instead.

The present findings indicate that enrichment strategies for dogs may be more effective when targeting senses that are behaviourally and ecologically relevant, particularly smell. Using colour visual cues to enhance the welfare of dogs may not be the most effective approach, given that they have not shown any preference for it. Instead, dogs may respond more strongly to scent-based enrichment tools, which have been shown to increase play behaviours and interactions, providing more positive behavioural interactions through these stimuli (Murtagh et al., 2020). While colour alone may have a limited impact on dog behaviour and welfare, it could still contribute as part of a multi-sensory enrichment tool combined with smell, sound, texture, or movement to create a more engaging and welfare-enhancing experience than visual cues alone. Previous research has indicated that dogs use colour and brightness together for enhanced detection of stimuli (Byosiere et al., 2019), and that combining texture, scents and colours in the environment through toys can encourage play behaviour and positive experiences (Amaya et al., 2020).

The findings from this study indicate that no one colour would be better than others for use in enrichment, as there was no evidence of a population preference, and only weak individual preferences. Consequently, if owners choose a particular colour for aesthetic reasons or personal

preference, it is unlikely to negatively affect the dog. Opting for neutral or natural-coloured items could also reduce costs and potentially minimise exposure to dyes or pigments that are unnecessary, as they add no extra benefit to their environmental enrichment compared to coloured objects.

4.5 Future Directions

If this study were to be repeated, several modifications could help clarify dogs' colour preferences more definitively. Increasing the number of trials and testing days would provide greater statistical power to detect differences from chance at the individual dog level. Similarly, expanding the sample size and including a broader variety of dogs would better represent the population and allow exploration of differences in preferences based on individual factors such as age, breed, sex, and use (e.g., farming, hunting, or companion dog, etc.). However, this would not be effective unless the testing method was also changed to reduce the side bias that tended to interfere with any colour choice.

Using a different stimulus and a varying method of presentation could reduce the effect of location biases and isolate colour choice. Presenting each colour individually in the same location could remove side bias and assess preference by primarily measuring behaviours such as latency to reach bowl, duration of time spent and number of revisits. However, it would be more difficult to analyse based solely on these interactions and subtle behavioural changes, with no clear marker to interpret what is considered a preference.

Some preference test methods have been designed using images presented on a screen, and the animal has to touch the screen to choose their preferred choice (Chow et al., 2017; Hopper et al., 2019). These usually involve teaching the subject to touch the screen, and they receive a reward linked to their choice. For example, the preference of food in non-human primates was analysed using a pair–wise touchscreen test; two different food options were presented on the screen simultaneously, and whichever one the subject chose, they would receive as a reward. They were only given one opportunity to choose, similar to a fixed choice preference test, and their preference could be analysed based on their most frequent choice (Hopper et al., 2019).

A similar method could be used with dogs by training them to present a certain behaviour, such as paw at or touch the screen with their nose to make a choice, which may then result in a reward. The reward would need to be the same for all colours to ensure their choice is based only on the colour and not on different reward values.

This method could be limiting because of the time it would take to teach all dogs to touch the screen and make the association between their choice and a reward. It would also not allow other interactions to be observed and would be based solely on the first choice. Minor interactions such as head tilt or directional gaze could potentially be analysed, but this can be very biased based on human interpretations.

Using a different method of preference testing could minimise the location bias and test the strength of preference. This can be done but putting the least preferred stimulus in the most preferred location and seeing if the animal is willing to forfeit the location, or vice versa. By doing so, it shows how much the animal values that preference, whether it be for the location or colour, and what they are willing to give up for this. Another method to test the strength is to remove the reward from the preferred colour or location and see if they still favour this. For example, presenting the three bowls, but removing the food from the right location, as most dogs favoured this side, could then analyse if they change their decision or still visit this location first based on the strength of this preference.

It would also be useful to investigate colour preferences without using food as the primary motivator. While food is a strong incentive, it may confound the results as the dogs focus more on the reward rather than the colour stimuli. Exploring alternative motivators such as different coloured toys (Hunt et al., 2022) might allow a clearer assessment of colour preferences independent of food motivation.

Alternatively, if food were to be used, this could be tested using different coloured food, which would be the preference itself. If dogs were presented with food that was all the same but designed in different colours, such as red, yellow and blue, this could be presented randomly in a free choice preference test method, and the same variables used in this study could be measured

based on which feed was interacted with or eaten the most. Similar testing has been done in humans using food that only differs in appearance to identify any visual preferences (Spence, 2015; Spence et al., 2010). This would engage the dog through their food drive whilst keeping the colour as the primary motivator, and could also be measured in various locations and presentations to limit side bias, such as scattering a certain amount randomly on the floor. Although in theory this method would be sufficient for testing colour preference, it would be difficult and expensive to get food made in the specific colours needed without changing the taste at all. Some dogs are also not as food motivated, as evident in this study by the varying latencies and some not finishing all their food; So individual results may vary based on their drive rather than anything to do with their preference.

4.6 Conclusion

This study found no strong evidence that dogs exhibit a colour preference when presented with yellow, blue, and red food bowls. Some weak evidence was found of a preference for the red coloured bowl, but it required repeated testing to differentiate if it was a significant preference. In contrast to previous studies, no dog showed any evidence of a preference between yellow and blue. There was a significant preference for location at both the individual and population level, mostly towards the right location.

These results suggest that colour alone may not be a primary factor that dogs consider when making a decision in this context. Rather, a combination of environmental factors may have affected their choice, including the fact that the right bowl was the first one visible when the door opened. Additional trials per dog and/or a larger sample size would be beneficial for further investigation.

These results suggest that, when designing or choosing enrichment items for dogs, colour by itself may not be important. Therefore, the selection of toys and enrichment items should prioritise enhancing other sensory modalities to promote positive interactions. However, the results also suggest that there is no harm in choosing stimuli marketed towards the owners' preferences for colour.

Moving forward, future studies should aim to refine methodologies to better isolate true colour preferences. This could involve using different rewards as motivation, controlling for side biases, increasing sample sizes and conducting tests in a more natural environmental setting.

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Appendices

Appendix A. Dog Questionnaire Given to All Interested Candidates to Assess Eligibility to Take Part in This Study

Dog Questionnaire

This questionnaire is intended to assist in completing my study to understand if dogs have a colour preference.

There is little scientific information available on whether dogs have a colour preference if given a choice between different coloured objects. As owners, understanding dogs' visual preferences can assist in providing them with positive experiences and the best welfare possible. If we know what a dog's preference is, we can include it in their environment and the items they use every day. My study will investigate if dogs show a preference using different coloured food bowls, using food that they are familiar with. Preference will be measured by their types of interactions, and number of times each bowl is chosen. The behaviour of each dog will be recorded and analysed individually. The results will be available for all participating owners who would like to know if their dog has a preferred colour and what that is, as well as what the overall preference results are.

This study will take place at Massey University, consisting of three, one hour-long trial periods that will take place on three separate days. There will also be a habituation session prior to testing to make sure your dog is comfortable in this environment. If you wish to take part in the trial, please fill out the questionnaire below. If you are chosen to participate, you will be required to bring your dog and some of the food they are currently eating to every session.

If you have more than one dog you would like to participate, please fill out a questionnaire for each dog individually.

Thank you for taking the time to complete this questionnaire. The information you provide will help us understand your dog and assist in completing this trial.

All responses will be kept confidential.

* Indicates required question

1. Email *

Owners Information

2. Full Name *

3. Contact Number *

4. Are you based in the Manawatu? *

Mark only one oval.

- Yes
- No

5. Do you have personal transportation available *

Mark only one oval.

- Yes
- No

6. Will you be available between January and March 2025? *

Mark only one oval.

- Yes
- No

7. Will you be available to attend the four one-hour sessions (Including the * habituation session) at Massey University to participate in this trial?

Mark only one oval.

Yes

No

8. What days of the week are you available? *

Check all that apply.

- Monday
- Tuesday
- Wednesday
- Thursday
- Friday
- Saturday
- Sunday

9. What time of day are you available? *

Please be specific. (e.g., Sundays 2 p.m, Wednesdays 10 a.m)

Basic Information

10. What is your dog's name? *

11. What is your dog's age? *

12. What breed(s) is your dog? *

13. What gender is your dog? *

Mark only one oval.

- Male
- Female

14. Is your dog desexed? *

Mark only one oval.

- Yes
- No

15. How long have you had your dog? *

_____

Living Situation and Behaviour

16. Do you have any other dogs that live with you? *

Mark only one oval.

- Yes
- No

17. Is your dog friendly around unfamiliar people? *

Mark only one oval.

- Yes
- No

18. Is your dog comfortable being left alone for short durations? *

Mark only one oval.

- Yes
- No

19. Is your dog used for work (e.g., farming, hunting, service dog)? *

Mark only one oval.

- Yes
- No

20. If you selected yes to the question above, please specify:

_____

21. Is your dog comfortable travelling? *

Mark only one oval.

- Yes
- No
- No Experience

22. Is your dog comfortable using stairs or an elevator? *

Mark only one oval.

- Yes
- No
- No Experience

Health Conditions

23. Does your dog have any history of health conditions? *

Mark only one oval.

Yes

No

24. If you selected yes to the question above, please specify:

25. If they do have any health conditions, does this affect their ability to eat?

Mark only one oval.

Yes

No

Feeding Information

26. How often do you feed your dog and what time(s) of day? *

27. What type of bowl do you use for feeding? *

e.g., Slow feeder, round, raised bowl, shallow bowl:

28. What material is your dog's bowl? *

e.g., Plastic, stainless steel:

29. What colour is your dog's bowl? *

30. What food do you feed your dog? *

Brand and feed type (e.g., kibble, raw feed diet, biscuits)

31. How much food does your dog get each feed? *

Please state measurements used.

32. How does your dog behave when being fed? *

e.g., slow feeder, fast eater, aggressive, territorial, graze feeder:

Motivation and Special Requirements

33. What motivates your dog the most? *

e.g., Food, pats, praise, toys, social interaction:

34. Does your dog have any other special requirements that should be noted?

e.g., Behavioural, dietary, specific training that may interfere with the trial:

Thank you for providing this information. It will greatly assist us in understanding and accommodating your dog's needs to participate in this trial. If you have any additional comments or questions, please feel free to include them below.

35. Additional Comments:

36. **Consent:** *

By signing this questionnaire, you acknowledge that the information above is all correct and may be used to assess if your dog is eligible to take part in this trial. If your dog fits the criteria and is selected to partake in this study, you consent to the data being used and represented as part of my research thesis to represent the study group.

To Consent, please sign with your Name and todays date (dd/mm/yy)

Appendix B. Recruitment Information Sheet Used to Recruit Participants

Do dogs show colour preferences in a free choice test?

Hi, I'm Jody Soanes, a student at Massey University. For my Master's research, I'm investigating dogs' colour preferences using a free choice test. You and your dog are invited to participate. Please read the following to understand why this research is being done and what your participation will involve.

Purpose of research: Dogs see colour differently from humans; they are red-green colour-blind and mostly see in shades of yellow, blue and grey. My research aims to determine whether dogs show a preference for a particular colour in their visible spectrum. This will be explored by presenting dogs with different coloured bowls containing a small amount of their usual food.

What will happen: If your dog is eligible, you will be required to bring them into Massey University on four separate days. Each visit will take approximately one hour.

Visit one: This will help your dog get used to the elevator up to the test room and the room itself and is a chance for us to meet and discuss any questions you have. You will need to bring a small sample of your dog's regular food. Your dog will be introduced to the testing areas; their regular food will be placed in the room to encourage your dog to explore with you present. This will be repeated to test their willingness to enter the room without you. During this time, we will monitor your dog's behaviour for signs of anxiety to ensure they will be comfortable during testing. If everything goes smoothly, we will progress to testing at the next visit. If your dog doesn't adapt well to the research environment, an additional visit may be required before testing begins. Note that you may choose to remove your dog from the study at any time.

Prior to testing: For 2 weeks before testing your dog will need to be fed only from a colourless metal bowl (provided if you don't have one already).

Visits two to four: Approximately a week after the familiarization visit, you will return with your dog at an allocated time; they should not be fed for at least 8 hours prior to arriving. Instead, please bring their missed meal with you as this will be used during the trial. Testing will occur once per week for 3 consecutive weeks.

Testing procedure: Each day will consist of six trials, each 2 minutes long, with a 5-minute break during which your dog will return to the waiting area with you (total 60 minutes). In the test room, 3 different coloured bowls will be presented, each with a small equal portion of your dog's usual food, along with video cameras to monitor your dog's behaviour.

At the beginning of each trial, you will walk your dog to the test room entrance and let them enter on their own, closing the door behind them. Nobody else will be present in the room. After 2 minutes you will open the door, and your dog will return to the waiting area while we reset the room. If your dog becomes agitated before the end of the 2 minutes or is unwilling to enter the room, the trial will be terminated. You may bring a blanket or toys to keep in the waiting room to

make your dog comfortable between trials.

Determining colour preferences: We will use the videos to determine whether your dog shows a preference based on which bowl they approach first, how many times they visit each bowl and the time spent interacting with each bowl. These data will be used to assess colour preferences at the individual and study population level.

Benefits of this research: At the end of the 4 visits, we will provide you with a petrol voucher as a token of our appreciation. We will also provide you with information about your dog's responses (favourite colour) and a summary of the overall findings of the study. You may find this information useful to select objects and toys for your dog in future.

Eligibility: If you are interested in participating, please complete the questionnaire to see if your dog is eligible. Your (anonymized) responses may also be used in my thesis to demonstrate the selection criteria used. To check your dog's eligibility, follow the link or QR code to complete the questionnaire: https://forms.gle/s339efaEaWq1BpHF7

You will be contacted to let you know whether your dog has been selected.

Thank you for considering participation in my study. We look forward to hearing from you!

Jody Soanes
Postgrad MSc (Animal Science)
[redacted]

Appendix C: Individual Dog Results, Provided to the Owners After Testing Was Completed.

Figure 1. Percentage of times that each bowl colour (red, yellow, blue) and location (left, middle, right) was visited first overall (across all 18 trials over three test days), and on each test day (across six trials on test day 1, 2, and 3). Data are shown for Billie only (a, c, e, g) and all 13 study dogs combined (b, d, f, h).

Overall, Billie chose the red bowl first more often than the yellow or blue bowls (Fig. 1a). There were some changes in Billie's responses over the three test days; the blue bowl was never selected first on day two or three (Fig. 1e, g), and red and yellow were selected equally often on day three (Fig. 1g). Billie's first choice selection showed a similar pattern to that of all dogs combined, apart from not visiting the blue bowl first on day two and three.

Billie selected the left-hand or middle bowls first more often than the right-hand bowl (Fig 1c, e, g). This differed to the results from all dogs combined, where there appeared to be a preference for selecting the right-hand bowl first (Fig 1b, d, f, h).

a) Billie overall

b) All dogs overall

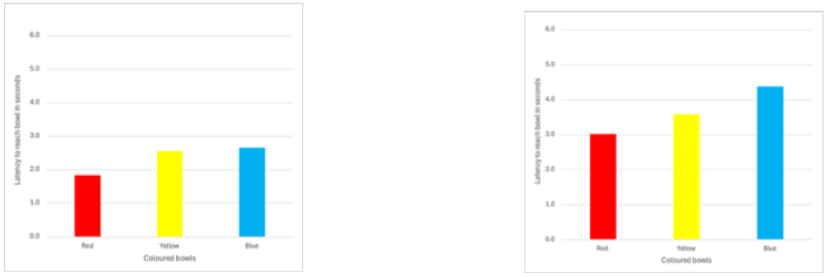
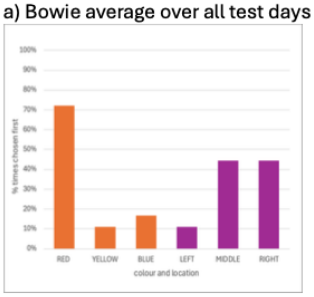


Figure 2. Latency in seconds (averaged across 18 trials over three test days) to visit the red, yellow, and blue bowls when each was chosen first. Data are shown for Billie (a) and all 13 study dogs combined (b).

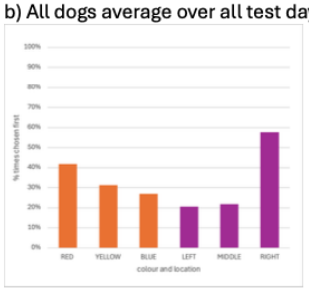
When Billie chose the red bowl first, he approached the bowl more quickly than when he selected yellow or blue first (Fig. 2a). Overall, Billie showed a similar pattern to all dogs combined, with the latency to visit the red bowl being shortest, followed by yellow, then blue (Fig. 2).

Bowie

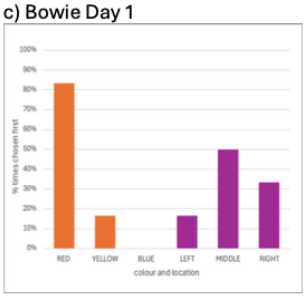
a) Bowie average over all test days



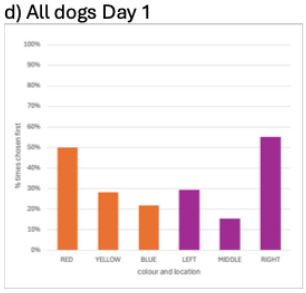
b) All dogs average over all test days



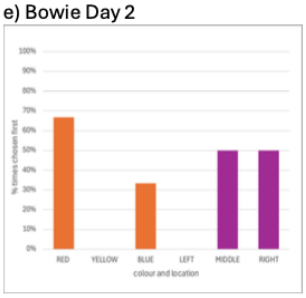
c) Bowie Day 1



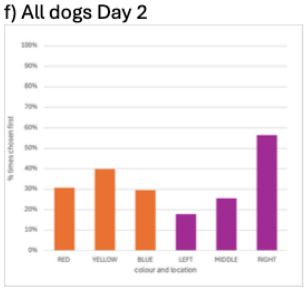
d) All dogs Day 1



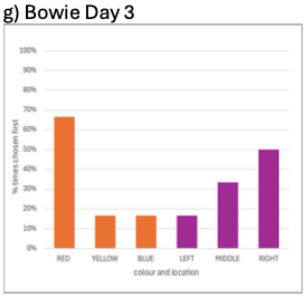
e) Bowie Day 2



f) All dogs Day 2



g) Bowie Day 3



h) All dogs Day 3

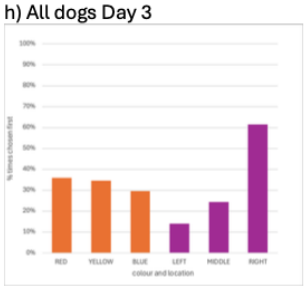
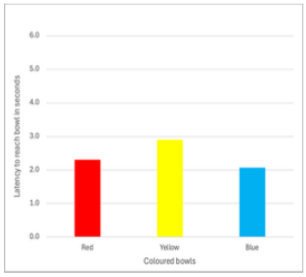


Figure 1. Percentage of times that each bowl colour (red, yellow, blue) and location (left, middle, right) was visited first overall (across all 18 trials over three test days), and on each test day (across six trials on test day 1, 2, and 3). Data are shown for Bowie only (a, c, e, g) and all 13 study dogs combined (b, d, f, h).

Overall, Bowie chose the red bowl first more often than the yellow or blue bowls (Fig. 1a). There were some changes in Bowie's responses over the three test days; the yellow bowl was never selected first on day two(Fig. 1e), and blue was never selected on day three (Fig. 1g). Bowie's first choice selection did not show a similar pattern to that of all dogs combined, picking red significantly more.

Bowie selected the right-hand or middle bowls first more often than the left-hand bowl (Fig 1c, e, g). This differed to the results from all dogs combined, where there appeared to be less preference for selecting the middle bowl first (Fig 1b, d, f, h).

a) Bowie overall



b) All dogs overall

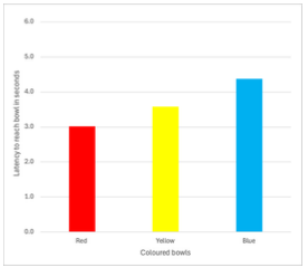


Figure 2. Latency in seconds (averaged across 18 trials over three test days) to visit the red, yellow, and blue bowls when each was chosen first. Data are shown for Bowie (a) and all 13 study dogs combined (b).

When Bowie chose the blue bowl first, he approached the bowl more quickly than when he chose yellow or red (Fig. 2a). Overall, Bowie did not show a similar pattern to all dogs combined, whom differed with the latency to visit the red bowl being shortest, followed by yellow, then blue (Fig. 2).

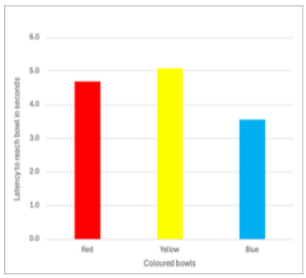
Cino

Figure 1. Percentage of times that each bowl colour (red, yellow, blue) and location (left, middle, right) was visited first overall (across all 18 trials over three test days), and on each test day (across six trials on test day 1, 2, and 3). Data are shown for Cino only (a, c, e, g) and all 13 study dogs combined (b, d, f, h).

Overall, Cino chose the Yellow bowl first more often than the red or blue bowls (Fig. 1a). There were some changes in Cino's responses over the three test days; there was no difference in colours picked in day one or two (Fig. 1c,e), and yellow was selected more often on day three (Fig. 1g). Cino's first choice selection showed a similar pattern to that of all dogs combined, apart from picking yellow slightly more than red.

Cino selected the left-hand bowl first more often than the middle or right-hand bowl (Fig 1c, e, g). This differed to the results from all dogs combined, where there appeared to be a preference for selecting the right-hand bowl first (Fig 1b, d, f, h).

a) Cino overall



b) All dogs overall

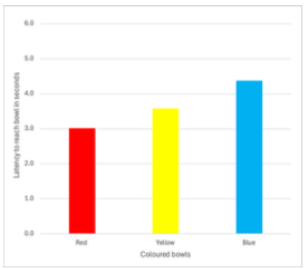
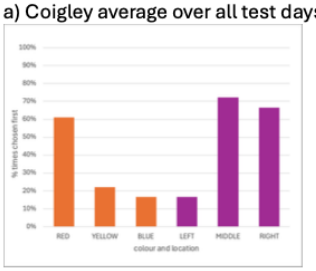


Figure 2. Latency in seconds (averaged across 18 trials over three test days) to visit the red, yellow, and blue bowls when each was chosen first. Data are shown for Cino (a) and all 13 study dogs combined (b).

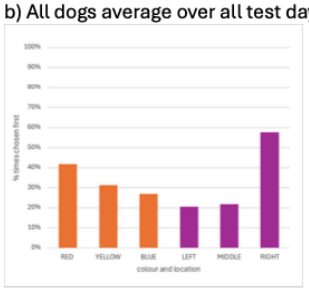
When Cino chose the blue bowl first, he approached the bowl more quickly than when he selected yellow or red first (Fig. 2a). Overall, Cino did not show a similar pattern to all dogs combined, whom had the latency to visit the red bowl being shortest, followed by yellow, then blue (Fig. 2b), whereas Cino had almost opposite results.

Coigley

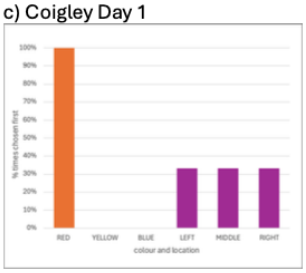
a) Coigley average over all test days



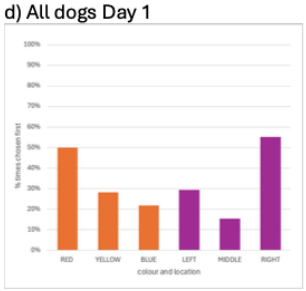
b) All dogs average over all test days



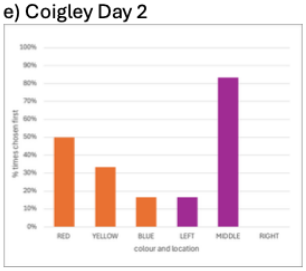
c) Coigley Day 1



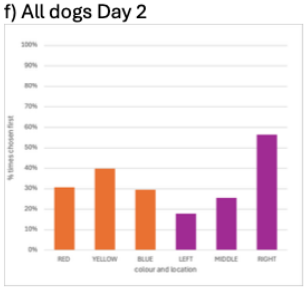
d) All dogs Day 1



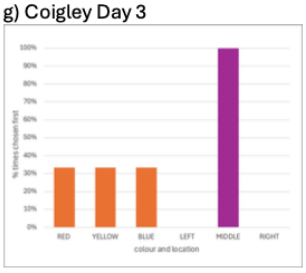
e) Coigley Day 2



f) All dogs Day 2



g) Coigley Day 3



h) All dogs Day 3

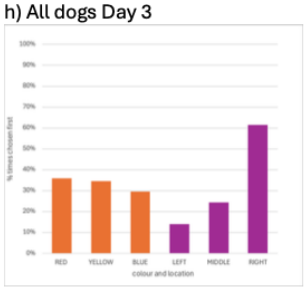


Figure 1. Percentage of times that each bowl colour (red, yellow, blue) and location (left, middle, right) was visited first overall (across all 18 trials over three test days), and on each test day (across six trials on test day 1, 2, and 3). Data are shown for Coigley only (a, c, e, g) and all 13 study dogs combined (b, d, f, h).

Overall, Coigley chose the red bowl first more often than the yellow or blue bowls (Fig. 1a). There were some changes in Coigley's responses over the three test days; the blue and yellow bowls were never selected first on day one (Fig. 1c), and all colours were selected equally often on day three (Fig. 1g). Coigley's first choice selection showed a similar pattern to that of all dogs combined, apart from the lower frequency of visiting the blue and yellow bowls.

Coigley selected the middle bowl first more often than the left-handed or right-hand bowl (Fig 1c, e, g). This differed to the results from all dogs combined, where there appeared to be a preference for selecting the right-hand bowl first (Fig 1b, d, f, h).

a) Coigley overall

b) All dogs overall

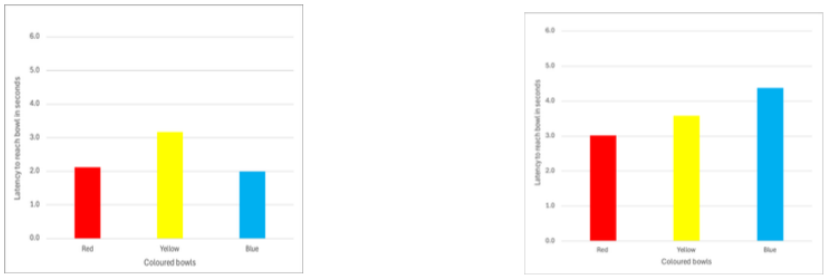


Figure 2. Latency in seconds (averaged across 18 trials over three test days) to visit the red, yellow, and blue bowls when each was chosen first. Data are shown for Coigley (a) and all 13 study dogs combined (b).

When Coigley chose the blue bowl first, he approached the bowl more quickly than when he selected yellow or red (Fig. 2a). Overall, Coigley showed a similar pattern to all dogs combined, with the latency to visit the red bowl being shortest, but differed with latency for yellow and blue (Fig. 2).

Daisy

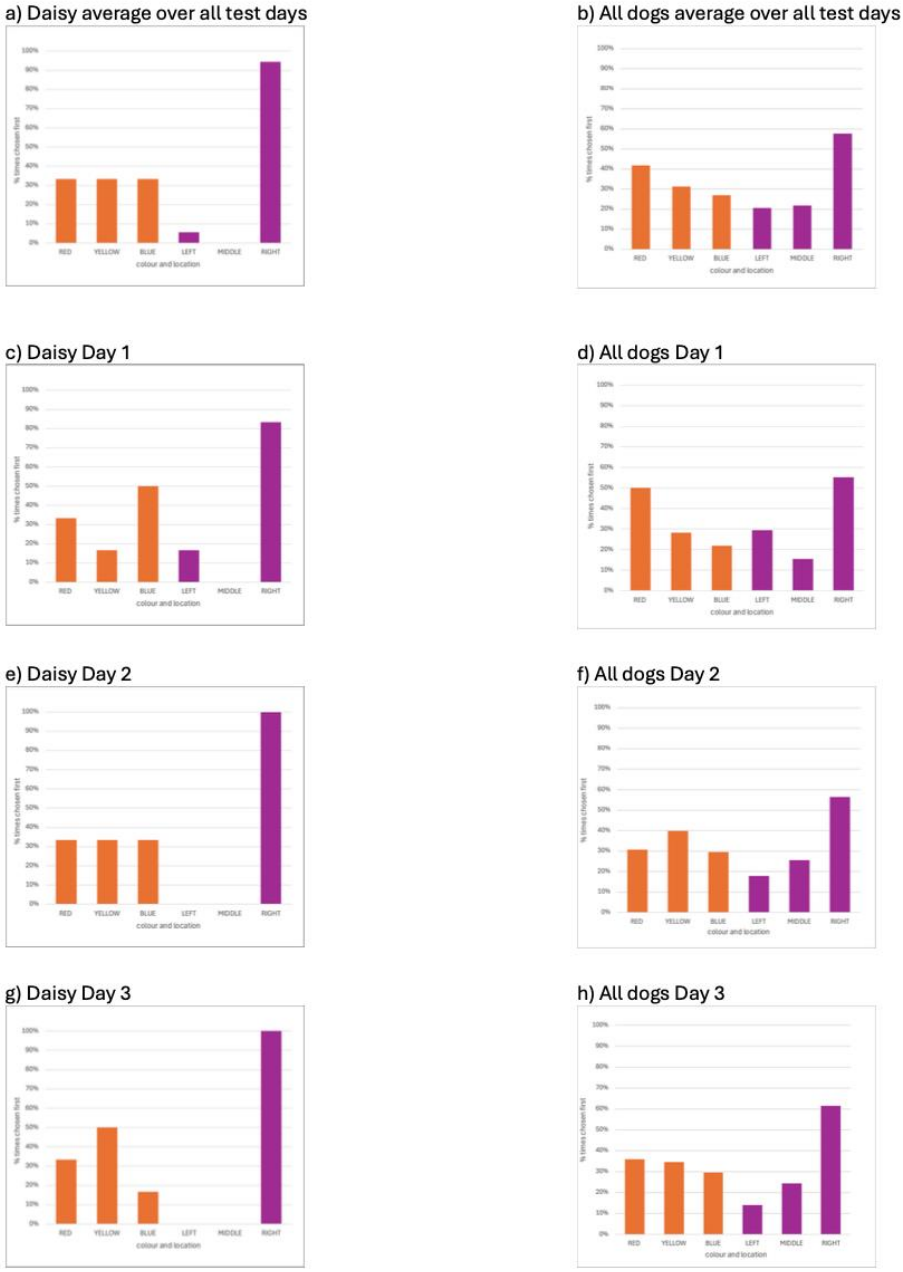


Figure 1. Percentage of times that each bowl colour (red, yellow, blue) and location (left, middle, right) was visited first overall (across all 18 trials over three test days), and on each test day (across six trials on test day 1, 2, and 3). Data are shown for Daisy only (a, c, e, g) and all 13 study dogs combined (b, d, f, h).

Overall, Daisy chose all the bowls the exact same amount of times first (Fig. 1a). There were some changes in Daisy's responses over the three test days; the yellow bowl was selected the least on day one, and blue the most (Fig. 1c), but yellow was selected the most on day three, and blue the least (Fig. 1g). Daisy's first choice selection showed a similar pattern to that of all dogs combined.

Daisy selected the right-hand bowl first more often than the middle or left-hand bowl (Fig 1c, e, g). This is similar to the results from all dogs combined, where there appeared to be a preference for selecting the right-hand bowl first (Fig 1b, d, f, h).

a) Daisy overall

b) All dogs overall

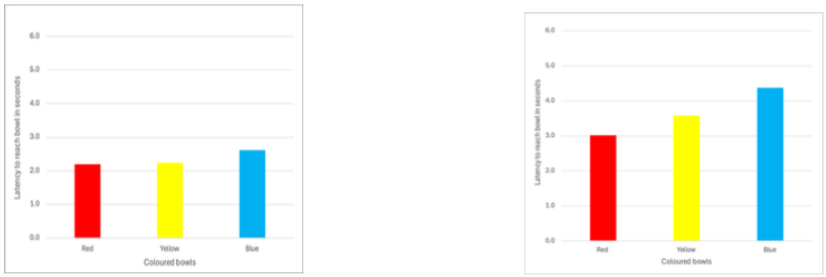


Figure 2. Latency in seconds (averaged across 18 trials over three test days) to visit the red, yellow, and blue bowls when each was chosen first. Data are shown for Daisy (a) and all 13 study dogs combined (b).

When Daisy chose the red bowl first, she approached the bowl more quickly than when she selected blue first, but she visited yellow with the exact same average time (Fig. 2a). Overall, Daisy showed a similar pattern to all dogs combined, with the latency to visit the red bowl being shortest, followed by yellow, then blue (Fig. 2).

Inky

Figure 1. Percentage of times that each bowl colour (red, yellow, blue) and location (left, middle, right) was visited first overall (across all 18 trials over three test days), and on each test day (across six trials on test day 1, 2, and 3). Data are shown for Inky only (a, c, e, g) and all 13 study dogs combined (b, d, f, h).

Overall, Inky chose the red bowl first more often than the yellow or blue bowls (Fig. 1a). There were some changes in Inky's responses over the three test days; All bowls were selected equally on day two and three (Fig. 1e, g), and red was selected more on day one (Fig. 1c). Inky's first choice selection for colour showed a similar pattern to that of all dogs combined.

Inky selected the right-hand bowl first more often than the middle or left-hand bowls (Fig 1c, e, g). This was similar to the results from all dogs combined, where there appeared to be a preference for selecting the right-hand bowl first (Fig 1b, d, f, h).

a) Inky overall

b) All dogs overall

Figure 2. Latency in seconds (averaged across 18 trials over three test days) to visit the red, yellow, and blue bowls when each was chosen first. Data are shown for Inky (a) and all 13 study dogs combined (b).

When Inky chose the yellow bowl first, she approached the bowl more quickly than when she chose blue for red first (Fig. 2a). Overall, Inky showed a similar result time to all dogs combined with a similar latency to visit the red bowl and blue, but she was faster to yellow than all dogs (Fig. 2).

Lilo

Figure 1. Percentage of times that each bowl colour (red, yellow, blue) and location (left, middle, right) was visited first overall (across all 18 trials over three test days), and on each test day (across six trials on test day 1, 2, and 3). Data are shown for Lilo only (a, c, e, g) and all 13 study dogs combined (b, d, f, h).

Overall, Lilo chose the yellow bowl first more often than the red or blue bowls (Fig. 1a). There were some changes in Lilo's responses over the three test days; All bowls were selected equally on day two and three (Fig. 1e, g), and yellow was selected more on day one (Fig. 1c). Lilo's first choice selection for colour showed a similar pattern to that of all dogs combined, apart from picking yellow over red more often.

Lilo selected the right-hand bowl first more often than the middle or left-hand bowls (Fig 1c, e, g). This was similar to the results from all dogs combined, where there appeared to be a preference for selecting the right-hand bowl first (Fig 1b, d, f, h).

a) Lilo overall

b) All dogs overall

Figure 2. Latency in seconds (averaged across 18 trials over three test days) to visit the red, yellow, and blue bowls when each was chosen first. Data are shown for Lilo (a) and all 13 study dogs combined (b).

When Lilo chose the blue bowl first, she approached the bowl more quickly than when she selected yellow or red first (Fig. 2a). Overall, Lilo did not show a similar pattern to all dogs combined, whom had the latency to visit the red bowl being shortest, followed by yellow, then blue(Fig. 2), which is almost then opposite of Lilo's results.

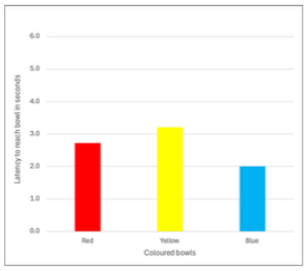
Moss

Figure 1. Percentage of times that each bowl colour (red, yellow, blue) and location (left, middle, right) was visited first overall (across all 18 trials over three test days), and on each test day (across six trials on test day 1, 2, and 3). Data are shown for Moss only (a, c, e, g) and all 13 study dogs combined (b, d, f, h).

Overall, Moss chose the red bowl first more often than the yellow or blue bowls (Fig. 1a). There were some changes in Moss's responses over the three test days; All bowls were selected equally on day two and three (Fig. 1e, g), and red was selected more on day one (Fig. 1c). Moss's first choice selection for colour showed a similar pattern to that of all dogs combined.

Moss selected the right-hand bowl first more often than the middle or left-hand bowls (Fig 1c, e, g). This was similar to the results from all dogs combined, where there appeared to be a preference for selecting the right-hand bowl first (Fig 1b, d, f, h).

a) Moss overall



b) All dogs overall

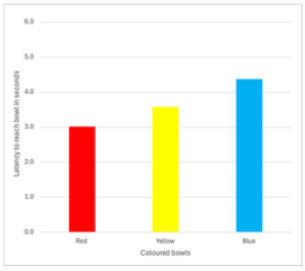
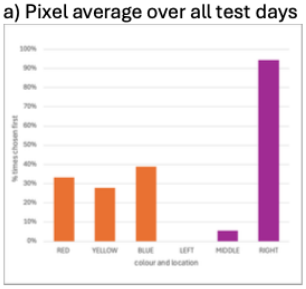


Figure 2. Latency in seconds (averaged across 18 trials over three test days) to visit the red, yellow, and blue bowls when each was chosen first. Data are shown for Moss (a) and all 13 study dogs combined (b).

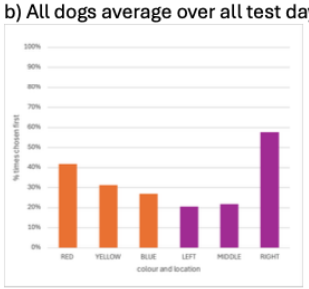
When Moss chose the blue bowl first, he approached the bowl more quickly than when he chose yellow or red (Fig. 2a). Overall, Moss did not have a similar result time to all dogs combined whom had the latency to visit the red bowl being shortest, followed by yellow, then blue (Fig. 2).

Pixel

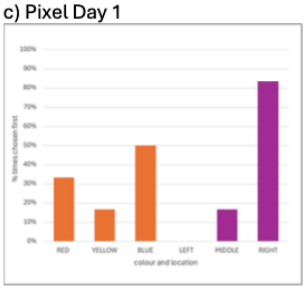
a) Pixel average over all test days



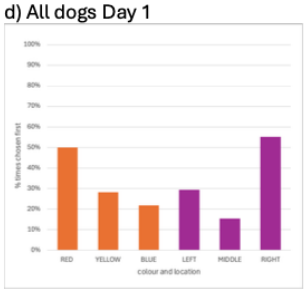
b) All dogs average over all test days



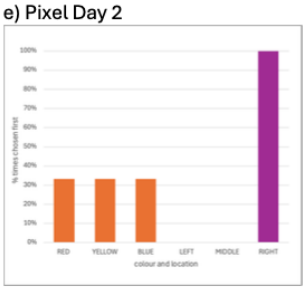
c) Pixel Day 1



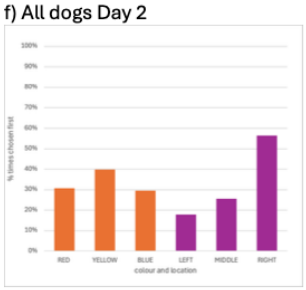
d) All dogs Day 1



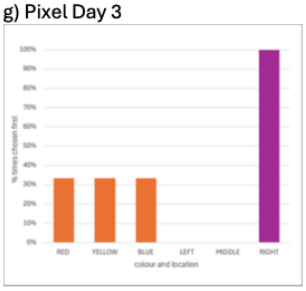
e) Pixel Day 2



f) All dogs Day 2



g) Pixel Day 3



h) All dogs Day 3

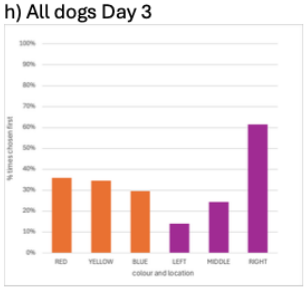


Figure 1. Percentage of times that each bowl colour (red, yellow, blue) and location (left, middle, right) was visited first overall (across all 18 trials over three test days), and on each test day (across six trials on test day 1, 2, and 3). Data are shown for Pixel only (a, c, e, g) and all 13 study dogs combined (b, d, f, h).

Overall, Pixel chose the blue bowl first more often than the red or yellow bowls (Fig. 1a). There were some changes in Pixel's responses over the three test days; All bowls were selected equally on day two and three (Fig. 1e, g), and blue was selected more on day one (Fig. 1c). Pixel's first choice selection for colour did not show a similar pattern to that of all dogs combined, they had chosen blue the least, followed by yellow then red .

Pixel selected the right-hand bowl first more often than the middle or left-hand bowls (Fig 1c, e, g). This was similar to the results from all dogs combined, where there appeared to be a preference for selecting the right-hand bowl first (Fig 1b, d, f, h).

a) Pixel overall

b) All dogs overall

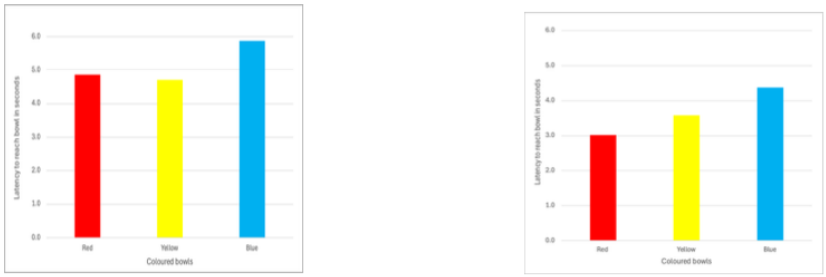
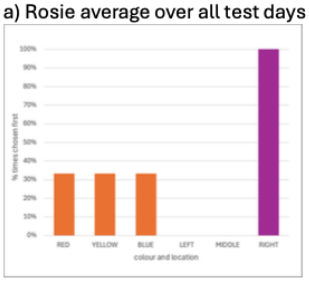


Figure 2. Latency in seconds (averaged across 18 trials over three test days) to visit the red, yellow, and blue bowls when each was chosen first. Data are shown for Pixel (a) and all 13 study dogs combined (b).

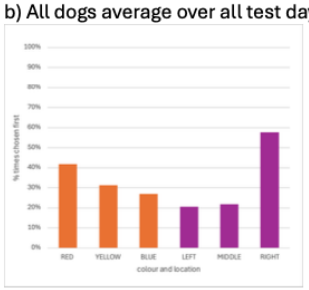
When Pixel chose the yellow bowl first, she approached the bowl more quickly than when she selected blue or red first (Fig. 2a). Overall, Pixel did show a similar pattern to all dogs combined, whom had the latency to visit the red bowl being shortest, followed by yellow, then blue(Fig. 2), differing with Pixel taking longer to red than yellow.

Rosie

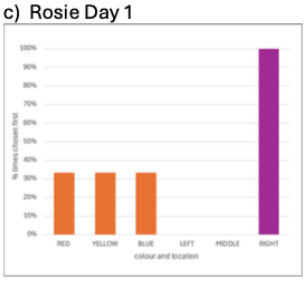
a) Rosie average over all test days



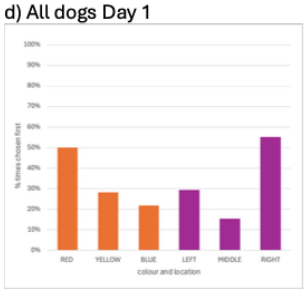
b) All dogs average over all test days



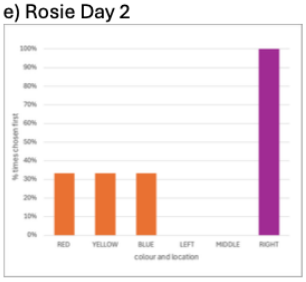
c) Rosie Day 1



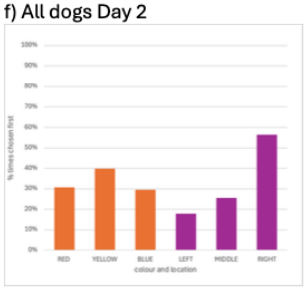
d) All dogs Day 1



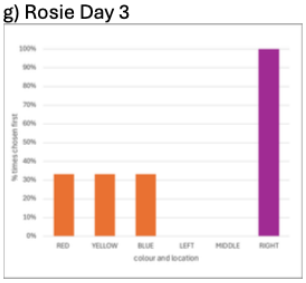
e) Rosie Day 2



f) All dogs Day 2



g) Rosie Day 3



h) All dogs Day 3

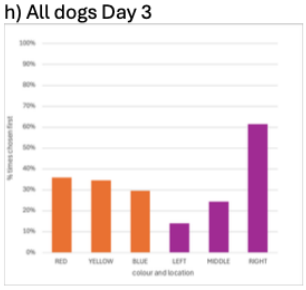
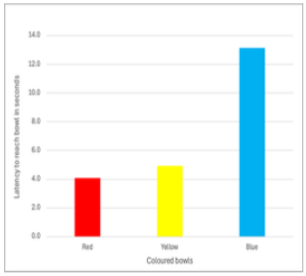


Figure 1. Percentage of times that each bowl colour (red, yellow, blue) and location (left, middle, right) was visited first overall (across all 18 trials over three test days), and on each test day (across six trials on test day 1, 2, and 3). Data are shown for Rosie only (a, c, e, g) and all 13 study dogs combined (b, d, f, h).

Overall, Rosie chose all bowls an equal amount if times first (Fig. 1a). There was no changes in Rosie's responses over the three test days; All bowls were selected equally on all three days (Fig. 1 c,e, g). Rosies's first choice selection for colour did not show a similar pattern to that of all dogs combined as she had no variation in her results.

Rosie selected the right-hand bowl first more often than the middle or left-hand bowls (Fig 1c, e, g). This was similar to the results from all dogs combined, where there appeared to be a preference for selecting the right-hand bowl first (Fig 1b, d, f, h).

a) Rosie overall



b) All dogs overall

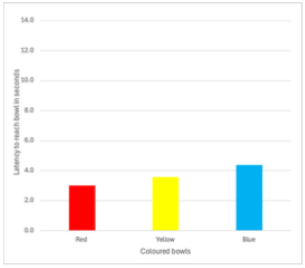
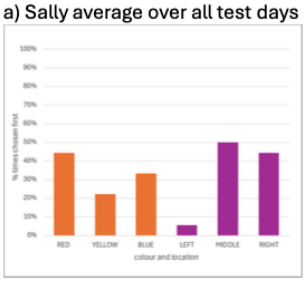


Figure 2. Latency in seconds (averaged across 18 trials over three test days) to visit the red, yellow, and blue bowls when each was chosen first. Data are shown for Rosie (a) and all 13 study dogs combined (b).

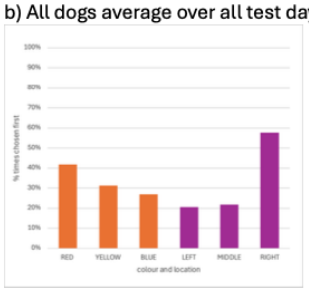
When Rosie chose the red bowl first, she approached the bowl more quickly than when she chose yellow or blue (Fig. 2a). Overall, Rosie had a similar result all dogs combined whom had the latency to visit the red bowl being shortest, followed by yellow, then blue (Fig. 2).

Sally

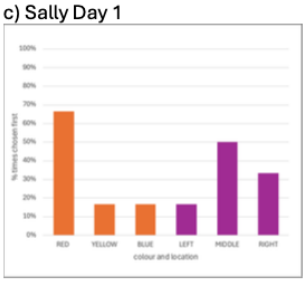
a) Sally average over all test days



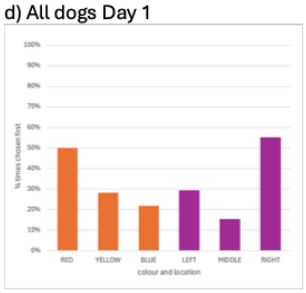
b) All dogs average over all test days



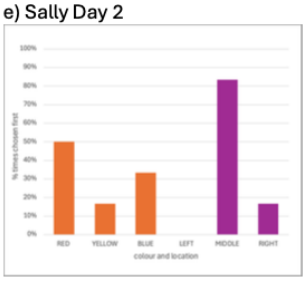
c) Sally Day 1



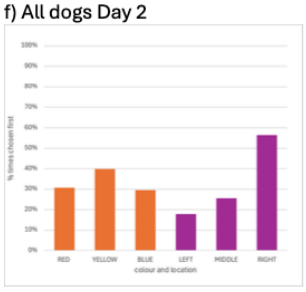
d) All dogs Day 1



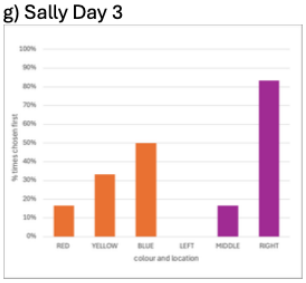
e) Sally Day 2



f) All dogs Day 2



g) Sally Day 3



h) All dogs Day 3

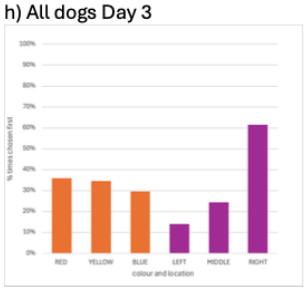
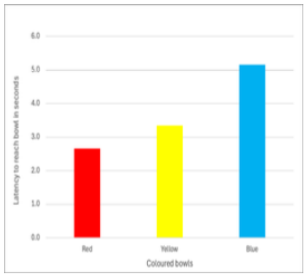


Figure 1. Percentage of times that each bowl colour (red, yellow, blue) and location (left, middle, right) was visited first overall (across all 18 trials over three test days), and on each test day (across six trials on test day 1, 2, and 3). Data are shown for Sally only (a, c, e, g) and all 13 study dogs combined (b, d, f, h).

Overall, Sally chose the red bowl first more often than the blue or yellow bowls (Fig. 1a). There were some changes in Sally's responses over the three test days; Red was selected first the most on days one and two (Fig. 1c, e), and blue was selected more on day three (Fig. 1g). Sally's first choice selection for colour did show a similar pattern to that of all dogs combined for frequency of red being picked, but differed between choice of yellow and blue.

Sally selected the middle bowl first more often than the right- hand or left-hand bowls (Fig 1c, e, g). This was not similar to the results from all dogs combined, where there appeared to be a preference for selecting the right-hand bowl first (Fig 1b, d, f, h).

a) Sally overall



b) All dogs overall

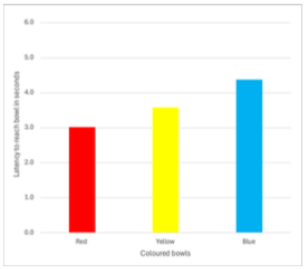


Figure 2. Latency in seconds (averaged across 18 trials over three test days) to visit the red, yellow, and blue bowls when each was chosen first. Data are shown for Sally (a) and all 13 study dogs combined (b).

When Sally chose the red bowl first, she approached the bowl more quickly than when she selected blue or yellow first (Fig. 2a). Overall, Sally showed a similar pattern to all dogs combined, whom had the latency to visit the red bowl being shortest, followed by yellow, then blue (Fig. 2).

Tui

Figure 1. Percentage of times that each bowl colour (red, yellow, blue) and location (left, middle, right) was visited first overall (across all 18 trials over three test days), and on each test day (across six trials on test day 1, 2, and 3). Data are shown for Tui only (a, c, e, g) and all 13 study dogs combined (b, d, f, h).

Overall, Tui chose the red and yellow bowls equally first, more often than the red bowls (Fig. 1a). There were some changes in Tui's responses over the three test days; All bowls were selected equally on day three (Fig.1g), Red was selected the most on day two (Fig.1e) and blue was not selected at all on day one (Fig. 1c). Tui's first choice selection for colour did show a similar pattern to that of all dogs combined, whom had chosen blue the least, followed by yellow then red, but differed that Tui had no difference between red and yellow.

Tui selected the right-hand bowl first more often than the middle or left-hand bowls (Fig 1c, e, g). This was similar to the results from all dogs combined, where there appeared to be a preference for selecting the right-hand bowl first (Fig 1b, d, f, h).

a) Tui overall

b) All dogs overall

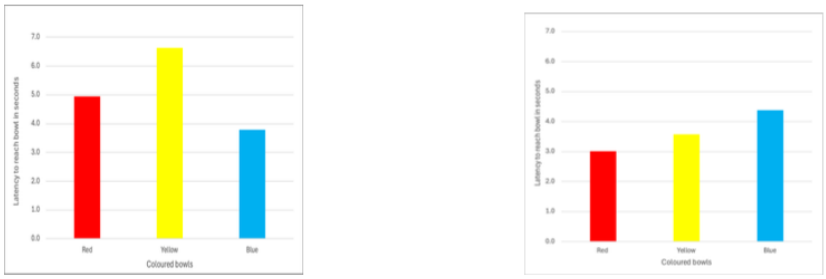
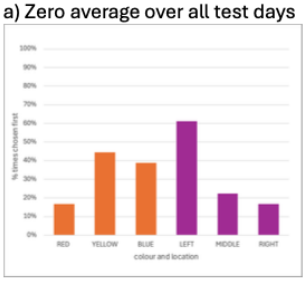


Figure 2. Latency in seconds (averaged across 18 trials over three test days) to visit the red, yellow, and blue bowls when each was chosen first. Data are shown for Tui (a) and all 13 study dogs combined (b).

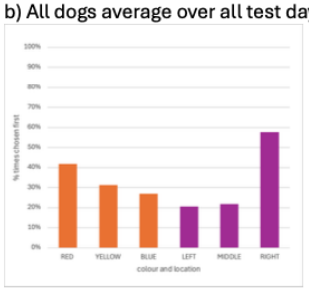
When Tui chose the blue bowl first, she approached the bowl more quickly than when she selected yellow or red first (Fig. 2a). Overall, Tui did show a similar pattern to all dogs combined, whom had the latency to visit the red bowl being shortest, followed by yellow, then blue(Fig. 2), differing with Tui being fastest to blue.

Zero

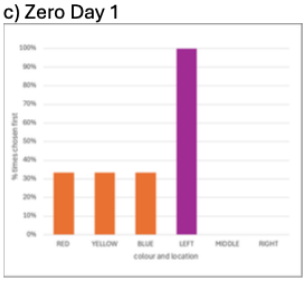
a) Zero average over all test days



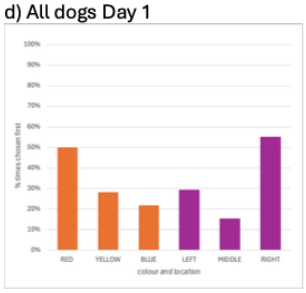
b) All dogs average over all test days



c) Zero Day 1

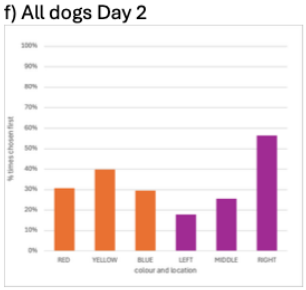


d) All dogs Day 1

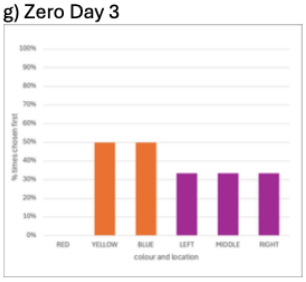


e) Zero Day 2

f) All dogs Day 2



g) Zero Day 3



h) All dogs Day 3

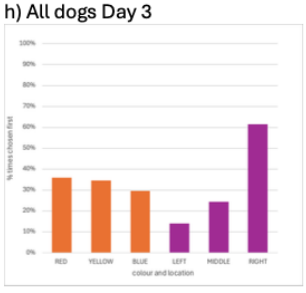


Figure 1. Percentage of times that each bowl colour (red, yellow, blue) and location (left, middle, right) was visited first overall (across all 18 trials over three test days), and on each test day (across six trials on test day 1, 2, and 3). Data are shown for Zero only (a, c, e, g) and all 13 study dogs combined (b, d, f, h).

Overall, Zero chose the yellow bowl first more often than the blue or red bowls (Fig. 1a). There were some changes in Zero's responses over the three test days; All bowls were selected equally on day one (Fig. 1c), yellow was selected the most on day two (Fig.1e) and red was not selected first at all on day three (Fig. 1g). Zero's first choice selection for colour did not show a similar pattern to that of all dogs combined whom had chosen blue the least, followed by yellow then red, whereas Zero chose red the least.

Zero selected the left-hand bowl first more often than the middle or left-hand bowls (Fig 1c, e, g). This was not similar to the results from all dogs combined, where there appeared to be a preference for selecting the right-hand bowl first (Fig 1b, d, f, h).

a) Zero overall

b) All dogs overall

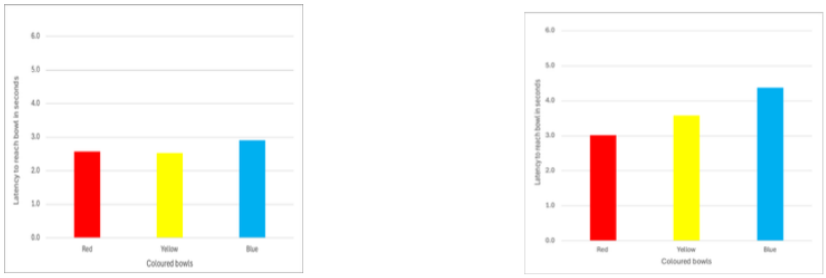


Figure 2. Latency in seconds (averaged across 18 trials over three test days) to visit the red, yellow, and blue bowls when each was chosen first. Data are shown for Zero (a) and all 13 study dogs combined (b).

When Zero chose the yellow bowl first, he approached the bowl more quickly than when he selected red or blue first (Fig. 2a). Overall, Zero showed a similar pattern to all dogs combined, whom had the latency to visit the red bowl being shortest, followed by yellow, then blue (Fig. 2). This only differed from Zero as he picked yellow slightly faster than red.