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Impact of Human-animal Interaction on the Behavioural Expression of Cats (*Felis catus*) and Dogs (*Canine lupus familiaris*).

A thesis presented in partial fulfilment of the requirements for the degree of

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Synopsis

Cats and dogs perceive and interpret the world differently from humans and the two species, which influences their behaviours and should be considered in the context of human-animal interactions to prevent problem behaviours and increase welfare. The common ancestors of both species had different hunting strategies, which is reflected in differences of their physical structure. Visual capacities also differ, and affect vision in the dark, movement detection capabilities, and acuity. Both have whiskers to provide information and utilise smell for gathering information. They have a wide range of hearing frequencies, which helps intra- and interspecies social communication. Cats and dogs are both affected by their social environment and genetics, which can influence their fear of humans and personality traits.

Animal behaviour is a broad field of study, with ethograms used as a tool to distinguish individual behaviours in cats and dogs. Behaviours that can be studied include active, inactive, and maintenance behaviours in cats and dogs. Traditional behavioural research has utilised observation by the owner or researcher. However, to examine animal activity and behaviour in a more natural setting, wearable technologies such as animal-borne cameras, pedometers, and accelerometers can be used. Triaxial accelerometers measure acceleration along three axes which can be correlated with observed activity and behaviour in both cats and dogs.

Human-animal relationships exist as psychological and physical bonds, which are influenced by humans (personality and attention), and the animal itself. Research into human interactions with cats and dogs has examined how human health can be affected either positively or negatively. Further research has examined how cats and dogs are affected physically and psychologically by this interaction. There have been multiple studies on problem behaviours and

prevention strategies. However, little is known of the effects of human-animal interactions on the behaviour and welfare of cats and dogs themselves.

Stress responses are commonly used as indicators of cat and dog welfare. Behavioural and physiological indicators of stress included changes in behaviours and/or non-specific markers such as blood pressure, heart and respiratory rates, or specific markers that include activity of the hypothalamic-pituitary-adrenal (HPA) axis and glucocorticoid levels. A minimally invasive method to determine HPA function in cats and dogs was to measure faecal glucocorticoid metabolite (FGM) concentrations over an extended period.

Knowledge of the effects of human-animal interaction on pet behaviour can be used to improve husbandry practices, resulting in better management practices and technology. The main objectives of this thesis were to determine if changes in the total duration and frequency of human-animal interaction had an impact on the activity levels and behavioural expressions of cats and dogs. A secondary objective was to assess FGMs as a tool to measure changes in stress levels within these animals.

Behaviours assessed were classified using previously validated random forest (RF) machine learning (ML) models developed with ActiGraph wGT3X-BT triaxial accelerometers in colony cats and dogs, which all fell under the broad behaviour categories of active, inactive, or maintenance behaviours. For cats the specific behaviours assessed included locomotion, eating, grooming, littering, lying, scratching, sitting, and standing over 28 days. For dogs these included barking, drinking, eating, locomotion, scratching, sniffing, lateral recumbency, lying head-down, lying head-up, sitting, and standing over 35 days. All animals were kept under normal colony conditions, with two additional sessions of human-animal interaction time at specified times (Monday, Friday) and during the respective study periods. Weather data and faecal sample

collection occurred concurrently to the study. Data analysis was conducted primarily using general linear mixed models (GLMM) in R (R Studio). Comparisons between groups and study period were examined to determine any effect of treatment.

Additional human-animal interaction resulted in significantly increased overall dynamic body acceleration (ODBA) in both species. Similarly, locomotive behaviour increased significantly throughout the trial in both cats and dogs. Among the cats, changes were observed only in the treatment group. However, changes occurred in both groups of dogs, indicating that the additional presence of the researcher could have also affected the control animals. Species specific changes included a significant decrease of scratching behaviour in cats, a trend of increased barking behaviour in dogs, and a significant decrease of sniffing among dogs.

Faecal glucocorticoid metabolite (FGM) concentrations were analysed using a faecal cortisol enzyme linked immune-sorbent assay (ELISA) and showed a decrease in glucocorticoid concentrations in both cats and dogs. This showed that additional interaction had the potential to increase welfare in colony cats and dogs, which may extend to the home setting.

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Chapter 1. Introduction

Animal welfare is a consideration of the mental and physical states of animals in an environment (Turner and Bateson, 2014), and factors in biological function and natural behaviour (Rochlitz, 2005; Bradshaw et al., 2012; Serpell, 2017). The first structured framework for animal welfare consideration was the five freedoms theory developed by the United Kingdom Animal Welfare Committee from the 1965 Brambell Report (McCulloch, 2013). This theory dictates that animals should have freedom from hunger or thirst, freedom from discomfort, freedom from pain, injury and disease, freedom to express normal behaviour, and freedom from fear and distress (McCulloch, 2013). The five domains model developed this further by incorporating and applying the principles of the five freedoms and to more practical domains such as nutrition, physical environment, health, and behavioural interactions, which in turn lead to the affective/mental state of the animal (Mellor et al., 2020).

Evaluating animal behaviour is recognised as a tool to assess animal welfare (Bayne, 2012; Bradshaw et al., 2012; Serpell, 2017). Behavioural observations are simple, mostly non-invasive, and abnormal behavioural expression implies compromised welfare (Bayne, 2012). Many studies have been conducted examining human-animal interaction, but most have only focused on the benefits provided for humans (Barker and Wolen, 2008; Friedmann and Son, 2009; Artemiou et al., 2021), with little focus on the companion animal themselves. The literature on domesticated farm animals such as poultry, pigs, and cattle includes studies that have examined the effects of human-animal interaction on the behaviour and health of the animal (Hemsworth et al., 1994; Rushen et al., 2001; Zulkifli, 2013). In contrast, studies of cats and dogs have focused on behaviours in different situations and environments (Smit et al., 2024; Redmond et al., 2025; Smit et al., 2025), rather than the influence of direct human presence and impact of interactions. This thesis aims to directly quantify the impact of human-animal

interaction on the behavioural expression of cats and dogs after considering their differences due to domestication, perception and interpretation, behaviour and cognition, general behaviours and measurement, and human-animal interaction.

Physiological measurements can also be used to gauge animal welfare in cats and dogs (Rochlitz, 2005; Turner and Bateson, 2014; Serpell, 2017). A stressed state may indicate poor animal welfare and could be measured physiologically through changes in blood pressure, heart rate, and respiratory rate (Rochlitz, 2005; Turner and Bateson, 2014; Serpell, 2017). More targeted measurements record activity of the hypothalamic-pituitary-adrenal (HPA) axis and glucocorticoid levels (e.g. cortisol), which Ahmed et al. (2023) reports as a key indicator of stress. One method that could quantify changes across a longer period of time involved measuring faecal glucocorticoid metabolite (FGM) concentrations using an assay such as an enzyme immuno-assay (EIA), which worked successfully in birds (Gholib et al., 2018), goats (Dulude-de Broin et al., 2019), cats (Kusuda et al., 2022), and dogs (Schatz and Palme, 2001). This thesis aimed to directly quantify the impact of human-animal interaction on the relative FGM concentrations throughout the duration of the study.

Knowledge of how human-animal interaction impacts pet behaviour and welfare could be used to improve husbandry practices, and it is our responsibility to explore opportunities for better plans, practices, and technology (MPI, 2013). The primary objective of this thesis is to answer the following questions:

1. Do changes in human-animal interaction duration and frequency affect the activity and behavioural expressions of cats and dogs?
2. How do behavioural expressions change over time?

3. How do changes in the duration and frequency of human-animal interactions affect the faecal glucocorticoid metabolite concentrations of cats and dogs?

Chapter 2. Literature Review

2.1 Domestication of Cats and Dogs

Domestication of cats and dogs likely occurred due to mutualistic interactions with humans that led to further interactions, selection, and breeding (Hu et al., 2014; Nilson et al., 2022; Tancredi and Cardinali, 2023). The interactions led to these species coexisting with humans and becoming part of human society. Years of selective breeding for behaviour, function, or appearance have led to these species being adapted into the present-day domestic cats and dogs.

The closest wild ancestor of domestic dogs (*Canis familiaris*) is the Gray Wolf (*Canis lupus*) (Metz et al., 2011; Serpell, 2017). Tancredi and Cardinali (2023) theorised that the most recent common ancestor of domestic dogs and the Gray Wolf had territories that overlapped with the ancient hunter-gathering humans. Utilising the same space facilitated opportunities for interaction. The first of three proposed theories of initial interaction was that the waste produced by humans allowed for the common ancestor to become a scavenger living near humans. The second theory was that the humans then captured, bred, and raised pups. The last theory was that the two species eventually developed mutualistic cooperation in hunting. These theories each have their own merit, aren't mutually exclusive, and are likely to have occurred at different stages of dog domestication. After the initial interaction and introduction into human society, desirable traits were gradually selected across generations, resulting in a split in the lineage of the common ancestor into present day domestic dogs and the Gray Wolf. This selection also likely resulted in neoteny, or persistence of baby features in the domestic species (Case, 2005).

The closest wild ancestor of domestic cats (*Felis catus*) is the African wildcat (*Felis silvestris*) (Krajcarz et al., 2020). Both Hu et al. (2014) and Nilson et al. (2022) suggested that the most recent common ancestor of domestic cats and the African wildcat essentially

domesticated themselves. This theory indicates that the common ancestor was attracted to pests (rats, mice) which were present at higher densities near human settlements as they became farmers and stored grain over winter. Being closer to settlements allowed for easier prey acquisition and facilitated the opportunity for interaction with humans. Like dogs, the interaction was mutualistic as cats could access prey and in turn controlled vermin and protected grain stores for the farmers. It appears that there has been less selection for cat traits across generations compared to dogs, resulting in cats largely retaining the same physical and functional traits from around 12,000 years ago, which is when some selection for aesthetic features finally began to occur (Nilson et al., 2022).

2.2 Perception and Interpretation

2.2.1 Body Structure

The bodily structure of present-day domestic cats and dogs likely reflects the movement and hunting strategies of their ancestors, which were ambush predators for cats (Case, 2003), and cursorial social hunters for dogs (Lea and Osthaus, 2018). As descendants of ambush predators, cats possess good jumping and climbing abilities, which provide a sense of safety and vantage points to assess their surroundings (Rochlitz, 2000). The African wildcat uses jumping retreats to hunt scorpions, jump to deliver a kill bite to the neck of larger prey, and climb into trees to hide in daytime (Herbst, 2009; Krajcarz et al., 2020). Dogs likely have retained good speed and endurance for hunting (Case, 2005), and possess the ability to hunt in packs, as seen in the Gray wolf (Metz et al., 2011; Serpell, 2017). Like a cat, dogs also possess the ability to jump, which is an essential part of their agility (Söhnel et al., 2020). Jumping is a common behaviour, such as in ball catching, but is sometimes viewed as a problem behaviour, such as when jumping on people (Polian et al., 2024). However, dogs do not have the righting reflex of a cat, which allows cats to

land safely from heights (Case, 2003), nor do they have the excellent balance and mobility of cats (Case, 2003), which enables them to access and move through a wider variety of terrain in a three-dimensional capacity compared to the dogs' more two-dimensional capacity.

2.2.2 Vision

Both cats and dogs have adaptions which improve their sight in darkness (Case, 2003, 2005). Cats have a *tapetum lucidum* that increases efficiency of light usage (Bradshaw et al., 2012), and more rods than cones across their entire retina (Steinberg et al., 1973). The resulting minimum amount of light that they can utilise to see in the dark is six times lower than that in humans (Gunter, 1951). As with cats, dogs also have a *tapetum lucidum* to increase efficiency of light usage (Miller and Murphy, 1995), but with a higher concentration of rods in only the centre of their retina (Kemp and Jacobson, 1992), which increases efficiency in the dark while retaining functional vision under bright environments (Miller and Murphy, 1995). The resulting minimum amount of light that dogs require to see in the dark is three times lower than that in humans (Case, 2005). Therefore, while both species have better vision in the dark than humans, cats have superior night vision than dogs.

Cats and dogs have increased movement detection capabilities (Miller and Murphy, 1995; Case, 2003, 2005; Bradshaw et al., 2012). Both species have a similar field of view, approximately 200-280 degrees (Case, 2005; Bradshaw et al., 2012). However, cats have monocular and binocular ranges of 80 and 120 degrees respectively (Case, 2003), while dogs have a monocular range of 135-150 degrees (Miller and Murphy, 1995) and a binocular range of 30-60 degrees (Case, 2005). This results in a wide field of view for both cats and dogs to locate prey, but differences in binocular vision, which results in variable depth perception (Miller and

Murphy, 1995), with the cats having a greater range of binocular vision which likely results in better depth perception.

In terms of visual acuity, or the ability of the eye to see at certain distances (Marsden et al., 2014), the cat has an estimated 20/150 vision while the dog has an estimated 20/75 (Ofri, 2013). This means that the cat needs to be at 20 feet to see what a human can see at 150 feet, while the dog needs to be at 20 feet to see what humans see at 75 feet. This suggests that cats are more nearsighted than dogs, which possibly aids in short range prey hunting when paired with the ability to detect movement with a wide field of view, and suggests that dogs have evolved to see further away, possibly to better spot and stalk prey. However, early life experiences and living environment can influence development of vision (Bradshaw et al., 2012).

2.2.3 Touch

Cats and dogs have whiskers which provide close range information and assists movement (Bradshaw et al., 2012; Vitale Shreve and Udell, 2015; Ha and Campion, 2019; Döring et al., 2025). Cat whiskers provide sensory information around the front of the face and compensates for their inability to see right under their noses (Bradshaw et al., 2012). The sensory information from whiskers also helps the cat move better in the dark (Bradshaw et al., 2012), and can also assist in determining whether they can fit through an opening (Ha and Campion, 2019). Although study in dogs is comparatively sparse, a recent study by Döring et al. (2025) has found that dog whiskers are functional and used in exploring the environment as well. This suggests that it may have a similar role as in cats when obtaining information at close ranges. Like in cats, whiskers also help dogs move better in the dark and determine if they can fit through an opening (Ha and Campion, 2019).

In addition to whiskers, cats use paws to distinguish temperatures (Finger and Norrsell, 1974) and manipulate objects (Boczek-Funcke et al., 1998). Finger and Norrsell (1974) found that cats could distinguish temperatures to the degree Celsius and appear to have a sensitivity comparable to primates, while there is a lack of literature on dog paw temperature sensitivity. Boczek-Funcke (1998) examined the shape of paws in food acquisition and object retrieval using x-ray and found that cats extend then abduct their digits to grip objects. Unfortunately, most studies of cat and dog paws have focused on paw preference (Wells, 2021; Simon et al., 2022) instead of how objects are manipulated by the paw. In these studies, it is implied that cats and dogs use their paws to stabilise any objects they are manipulating.

2.2.4 Smell

Compared to other features, smell is as significant in the survival of these species, as it is important for gathering information (Verberne and de Boer, 1976; Feldman, 1994; Gazit and Terkel, 2003; Lisberg and Snowdon, 2009; Horowitz et al., 2013; Serpell, 2017). Verberne and de Boer (1976) examined smell-associated behaviours in cats by observing the responses of cats to urine and cheek secretions. These cues elicited different responses according to the sex of the cat and provided social information such as the reproductive state of females (Verberne and de Boer, 1976), and territorial information (Feldman, 1994). For information gathering and detection in trained dogs, smell is more significant than vision (Gazit and Terkel, 2003; Horowitz et al., 2013), as it was found that trained sniffer dogs used their olfactory senses more heavily than visual senses even in areas with sufficient lighting (Gazit and Terkel, 2003). Smell is also used in dogs to obtain information about other dogs, such as during anogenital sniffing (Serpell, 2017), and sniffing of urine in scent marked environments (Lisberg and Snowdon, 2009). The vomeronasal organ assists in information gathering using scent and is associated with the

Flehmen response (Case, 2003, 2005). The Flehmen response is the intake of air and pheromones through the mouth and into the vomeronasal organ in cats (Hart and Leedy, 1987), and is likely similar to dogs.

Cats and dogs both possess the ability to discriminate many scents (Bánszegi et al., 2017; Bräuer and Belger, 2018; Lea and Osthaus, 2018). For example, Bánszegi et al. (2017) determined that mother cats could distinguish between their own and alien kittens by smell. Dogs are widely known to possess the ability to be trained for scent discrimination, which has been used to determine directions of scent trails, distinguish between people (Lea and Osthaus, 2018), and indicate the presence of drugs, bombs, and even some diseases (Bräuer and Belger, 2018). However, there is a lack of data on cat scent discrimination (Alvites et al., 2023) so it is not known which species has superior scent discrimination.

A unique facet of olfaction is the ability of certain plants such as catnip to induce specific behaviours (Case, 2003). These plant-based scents may cause shaking, salivation, rolling, agitation, and sudden bursts of locomotion (Coppin and Onofrio, 2024), resulting in a state of altered behavioural states and confusion. There is a lack of studies on similar phenomenon in dogs.

The significance of scent to both cats and dogs are greater than that in humans, with the importance likely higher in dogs as indicated by the presence of more olfactory cells (Case, 2003, 2005; Bradshaw et al., 2012). Cats have approximately 200 million olfactory cells (Bradshaw et al., 2012), dogs have at least 220 million (Case, 2005), while humans have only 5 million (Case, 2003, 2005). The number of olfactory cells suggests that smell is much more important in cats and dogs than humans, likely because they are predators and a good sense of smell can help in locating prey. While the olfactory bulb in dogs takes up a large proportion of

brain volume (Kavoi and Jameela, 2011), similar studies of cat olfactory bulb morphometry are rarer (Alvites et al., 2024), so it is not known exactly how the two species compare.

2.2.5 Hearing

As predators, good auditory senses such as hearing a wide range of frequencies are beneficial for cats and dogs (Case, 2003, 2005). Thus, they are adapted to hear a wide range of frequencies: 48 Hz to 85 kHz (Heffner and Heffner, 1985) in cats, and up to 40 kHz in dogs (Case, 2005). In addition, cats appear to have evolved high-frequency hearing without sacrificing low-frequency hearing (Heffner and Heffner, 1985). Guérineau et al. (2024) recently suggested, however, that the sensitivity in dogs is understudied, and that their perceived hearing thresholds are not yet fully understood. These hearing abilities likely allow cats and dogs to hear the communication of prey animals and use that cue to locate them due to overlapping frequency ranges (Case, 2005; Bradshaw et al., 2012).

Hearing also allows for both intra- and interspecies social communication in cats and dogs (Bradshaw et al., 2012; Serpell, 2017). Cats' social communication is used to express internal states with up to 21 different vocalisations (Tavernier et al., 2020). An example is the meow (Tavernier et al., 2020), which is more often seen in cat-human interaction but also seen in cat-to-cat communication socially, for reproduction, and for finding conspecifics. Social communication has also developed in dogs to maintain social relationships (Serpell, 2017). As descendants of pack hunters, communication is vital for dogs in situations of impaired vision, with barking as the main method, allowing for communication without vision of the target (Serpell, 2017).

2.3 Factors Influencing Behaviour and Cognition

2.3.1 Social Environment

The social environment is important in the development of cats (Bradshaw et al., 2012) and dogs (Harvey et al., 2016; Serpell, 2017), as it affects expressed adult behaviours. Human handling around 5-9 weeks of age in cats (Collard, 1967) and around 2.5-13 weeks of age in dogs (Freedman et al., 1961), has resulted in friendlier and less fearful individuals later in life, but with individual variation depending on treatment group with varying quantity of handlers (Freedman et al., 1961; Collard, 1967). It is also important for kittens and puppies to spend time with their mother and littermates to learn normal cat and dog behaviour (Case, 2003, 2005; Turner and Bateson, 2014).

2.3.2 Genetics

Genetics affects the behaviour of cats and dogs (Case, 2003; Serpell, 2017). For example, McCune (1995) found that kitten friendliness towards humans was influenced by the friendliness exhibited by their father even though they had no contact with him. In addition, kittens in the same litter tended to exhibit similar levels of behaviours to each other (Lowe and Bradshaw, 2001). In dogs, genetics also affects behavioural tendencies because dogs co-evolved with humans and were selected by them for their value in working (Serpell, 2017).

In terms of heritability, or the variability in behavioural tendencies due to genetics, the heritability of personality traits was reported to be between 0-0.53 for cats and 0-0.58 for dogs (Serpell, 2017; Salonen et al., 2019). This means that genetics could explain up to a 53% variability in cat behavioural tendencies and up to 58% variability in dog behavioural tendencies.

However, there are differences in both cat and dog behavioural tendencies depending on breed and data collection method (Salonen et al., 2019).

2.3.3 Theory of Mind

Theory of mind is the ability to anticipate the thoughts and goals of others (Leslie et al., 2004), and has the potential to explain animal behaviour. However, it is difficult to identify in animals due to the theory's focus on the human element (Karan, 2023). The Abilities in Theory of Mind Space (ATOMS) framework is a simplified representation of the theory of mind, and includes understanding intentions, desires, emotions, knowledge, perceptions, beliefs, and non-literal communication of humans (Beaudoin et al., 2020). In cats, studies show that they fulfil some of the categories of the ATOMS framework, including understanding intentions or desires (Mäses and Wascher, 2023), and the perception of humans (Zhang et al., 2021). In dogs, studies show that they fulfil categories such as intentions or desires (Dorey et al., 2010; Bray et al., 2021), non-literal communication (Schünemann et al., 2021), and perception of humans (Udell et al., 2011; Huber and Lonardo, 2023). This indicates that both cats and dogs possibly have a theory of mind.

2.4 General Animal Behaviour

Animal behaviour is a broad field of study. Among cat and dog behaviour, topics studied include the genetics, breed and gender, early experiences in development, feeding, sociality and communication, aggression, therapy, welfare, and human-animal relationship (Bradshaw et al., 2012; Serpell, 2017). To measure and quantify behaviours, ethograms, which describe behaviours that can and have been measured and analysed, are used as a tool to distinguish individual behaviours, which can help to better understand the behavioural repertoire of healthy

domestic cats and dogs (Roth and Jensen, 2015; Walker et al., 2016; Kappel et al., 2024). Analysis of published ethograms show that behaviours can be generalised into active, inactive, and maintenance behaviours in cats (Smit et al., 2023; Kappel et al., 2024) and dogs (Roth and Jensen, 2015; Walker et al., 2016; Redmond et al., 2024).

2.4.1 Active Behaviours

Active behaviours studied in cats and dogs that are more relevant to home and colony environments include, but are not limited to, climbing, digging, fighting, jumping, marking, playing, rolling, running, stretching, sniffing, trotting, walking, and vocalising (Roth and Jensen, 2015; Walker et al., 2016; Smit et al., 2023; Kappel et al., 2024; Redmond et al., 2024). Definitions of active behaviours for both cats and dogs are listed (see Table 2-1). Some of the behaviours are more species- or situation-specific and thus may not have a definition.

Table 2-1. Chart of active behaviours in cats and dogs. *From Roth and Jensen (2015); Walker et al. (2016); Smit et al. (2023); Kappel et al. (2024); Redmond et al. (2024)*

Active Behaviours	Definition (Cat)	Definition (Dog)	Notes
Climbing	Moving up or down a vertical object or structure by alternating use of both front and hind legs, with the pace set by the direction it is going (front legs if going up, hind legs if going down)	Not defined	
Digging	Breaking and moving substrate around with front paws, such as digging a hole, and results in substrate moving behind its hind legs	Using front paws to repeatedly scratch the walls and floor	May be hard to distinguish with littering as they are associated, hence had a low sample size and was removed from the behavioural model developed by Smit et al. (2024).
Fighting	Engaging in physical combat with the presence of piloerection of tail and back fur (Smit et al., 2024). May involve biting, where the cat sinks its teeth into its target (Kappel et al., 2024)	Not defined	
Jumping	Moving from one place to another by first lifting front legs off the ground then hind legs in a leaping motion. Smit et al. (2024) differentiated horizontal and vertical jumping.	State where less than or equal to two legs are in contact with the ground. Roth and Jenson (2015) distinguished jumping as towards another dog or in contact with humans, while Redmond et al. (2024) who drew the description from Walker et al. (2016) specified it as including contact with fencing, kennel, or person	
Marking	Includes urine marking, stroke marking, and scratch marking. Urine marking is urination on objects; stroke marking is rubbing glands of the body on surfaces; scratch marking is scratching and releasing scent from paw gland	Marking in dogs was not defined in the studied ethograms, and is likely categorised as urination	
Playing	Interaction with an object, person, or another cat in a non-aggressive manner. Play can be further categorised into object play, locomotor play, and social play (Kappel et al., 2024)	Not defined	

Stretching	Stand/walk and extend their legs outwards, becoming longer	Moving into a play bow position and extending legs
Sniffing	Smelling the body parts of other cats or doing the flehmen response	Directing the nose to a point of interest, such as an object, a person, or the ground, and inhaling air forcibly
Rolling	Rotating from one lateral recumbency, or the position lying down flat on a side with head resting sideways, to another, with all four paws in the air with belly exposed between rolls	Not defined
Vocalisation	Includes chattering, chirping, copulatory crying, growling, hissing, yawning, yowling, meowing, purring, sneezing, spitting, and trilling	Includes barking, howling, whining, and yelping
Running	Fastest movement that includes both a 3-beat gait gallop and a 4-beat asymmetric gait depending on speed. Any gait faster than a trot with a part where no paws are in contact with the ground (like the canter)	3-beat gait where two legs move separately and two as a diagonal pair and involves multiple paws leaving contact with the ground
Trotting	2-beat symmetric diagonal gait where diagonal front and hind legs contact the ground alternatively to support the body	2-beat symmetric diagonal gait where diagonal front and hind legs contact the ground alternatively to support the body
Walking	4-beat gait where each paw is moved in sequence. Split into slow walk, where three to four paws are in contact with the ground, and fast walk, where only two to three paws are in contact with the ground	Like walking in cats, but no specification of fast walk. Defined as slow movement where only one paw is off the ground at a time

2.4.2 Inactive Behaviours

Inactive behaviours of cats and dogs include, but are not limited to, lying/resting, sitting, squatting, and standing (Roth and Jensen, 2015; Walker et al., 2016; Smit et al., 2023; Kappel et al., 2024; Redmond et al., 2024). Explanations of inactive behaviours in cats and dogs are defined (see Table 2-2), with most definitions similar for the cat and dog.

Table 2-2. Chart of inactive behaviours in cats and dogs. *From Roth and Jensen (2015); Walker et al. (2016); Smit et al. (2023); Kappel et al. (2024); Redmond et al. (2024)*

Inactive Behaviours	Definition (Cat)	Definition (Dog)	Notes
Lying/resting	Body in a horizontal position, includes full and half lateral recumbency (laying on its side), dorsal recumbency (laying on the back), ventral recumbency (laying on belly), or curled lateral recumbency (laying curled up). May also be sleeping if the eyes are closed, head is on ground or body, and body moves in rhythm with breath	Like lying in cats, but can be classified as resting-alert where the head is off the ground, resting-asleep where the head is on the ground or body, or curled lateral recumbency	
Sitting	Position where the animal is upright with hind quarters on the ground, hind legs are flexed, or in a bent and tucked position, and front legs are fully extended to support the body	Position where the animal is upright with hind quarters on the ground, hind legs are flexed, or in a bent and tucked position, and front legs are fully extended to support the body	
Squatting	Touching the ground using all four feet with legs flexed, front paws placed directly in front of and under the body, and belly possibly touching the ground	Not defined	Differs from crouching, which is essentially squatting in the context of ambush
Standing	Position where all feet contact the ground and extend to support the body	Position where all feet contact the ground and extend to support the body	

2.4.3 Maintenance Behaviours

Maintenance behaviours of cats and dogs, or behaviours that support basic subsistence, include, but are not limited to, allogrooming, drinking, eating, grooming, littering, and sharpening claws (Roth and Jensen, 2015; Walker et al., 2016; Smit et al., 2023; Kappel et al., 2024; Redmond et al., 2024). Definitions of maintenance behaviours in cats and dogs are specified (see Table 2-3), with most similar when defined with some slight differences (e.g. drinking).

Table 2-3. Chart of maintenance behaviours of cats and dogs. *From Roth and Jensen (2015); Walker et al. (2016); Smit et al. (2023); Kappel et al. (2024); Redmond et al. (2024)*

Maintenance Behaviours	**Definition (Cats)**	**Definition (Dogs)**	**Notes**
Allogrooming	Loosely defined as licking the fur of another cat	Not defined	
Drinking	Lapping up water using tongue. Cats normally adopt a squat position and draw a column of water up using surface tension then bite into it	Lapping up water using their tongue. No posture specified for dogs	No posture specified for dogs
Eating	Ingestion, chewing, and swallowing of food. Cats normally adopt a squat position.	Ingestion, chewing, and swallowing of food.	No posture specified for dogs
Grooming	Licking, scratching, biting, and chewing various locations of the body to clean itself	Licking, scratching, biting, and chewing various locations of the body to clean itself	
Littering	Urinary and faecal excretion from the body	Urinary and faecal excretion from the body	
Sharpening claws	Sinking of claws into an object using alternate pulling movements. Essentially scratching of objects, and results in scratch marks and sharper claws	Not defined	

2.5 Measurement of Animal Behaviour

2.5.1 Observation

One of the most common ways to gauge activity levels and distinguish behaviour in pets is through owner-based questionnaires like the Fe-BARQ (Duffy et al., 2017) and C-BARQ (Duffy et al., 2014) for cats and dogs, respectively. Less intensive owner-based questionnaires are also commonly used for other purposes such as to ascertain specific impacts of treatments (Lascelles et al., 2001), or to generate behavioural time budgets for cats (Turner, 2021b). However, questionnaires rely heavily upon the subjective observations and memory of owners

(Turner, 2021b), which are subject to bias, while also possibly influencing the expressed behaviours due to the presence of humans. Observer effects are particularly prevalent in cats (Piccione et al., 2013), which are known to hide behaviours in the presence of other animals as it relates to survival (Horwitz and Rodan, 2018). A related issue is the stress felt by pets in a clinical setting which may also affect their expressed behaviours (Lind et al., 2017). This combination likely results in decreased quality of collected data using this approach.

Observations made directly or filmed by researchers are also used, such as in some previously cited sources (Collard, 1967; McCune, 1995; Walker et al., 2016; Bräuer and Belger, 2018; Bray et al., 2021; Turner, 2021a). Altmann (1974) stated that observational study methods could measure events and states using techniques such as focal animal sampling. They could use continuous or non-continuous sampling methods depending on the focus of the study. Continuous sampling method incorporates time, but is laborious, and can be affected by observer fatigue, which decreases the quality and accuracy of collected data. In contrast, non-continuous sampling methods only measure events, so data can only be reported as frequencies and not durations. Although there are clear drawbacks, observational sampling is still the base method for validating more modern technology and associated techniques such as with wearable technology (Lascelles et al., 2007; Lascelles et al., 2008; Shepard et al., 2008). Benefits include flexibility and application to different types of studies while limitations include high labour and time requirements (Bakeman and Quera, 2012).

Video tracking systems, such as Ethovision, have been used by researchers to track bouts of behaviour (Hansen et al., 2007; Lascelles et al., 2008). Benefits include reliable recording of behaviours depending on how it is coded to record, and no chance for human error such as observer fatigue to occur (Noldus et al., 2001). However, such systems can only be run in

controlled environments, may be restricted to specified dimensions, and involves the use of an overhead camera that cannot be hindered by furniture since the animal needs to be tracked (Hansen et al., 2007; Lascelles et al., 2008). This means that the ability to measure "natural" behaviours is reduced as the environment must be artificially set up for the system to work properly (Andrews, 2015).

2.5.2 Wearable Technology

To examine activity of animals in a more "natural" setting, wearable technology such as animal-borne cameras can be used (Loyd et al., 2013; Huck and Watson, 2019). This method has been used to study ecology and conservation by recording from the point of view of species such as falcons (Kane and Zamani, 2014), turtles (Heaslip et al., 2012), caribou (Thompson et al., 2012), sharks (Papastamatiou et al., 2019), cats (Loyd et al., 2013; Huck and Watson, 2019), and dogs (Bombara et al., 2017). The clearest benefit is that the point of view of the animal is the focal point, providing unique insights. Limitations include not only the ones mentioned in filmed observations (high labour and time requirements) but also that data gathered is restricted because the method is designed to record only what the animal is looking at and doing (Huck and Watson, 2019). The results cannot be utilised to directly measure behaviours of interest in the animal reliably and instead relies on inference of behaviours using the video footage. However, this method can be useful depending on the behaviour of interest.

Pedometers, such as the ones used on dogs by Chan et al. (2005), are wearable technology that measure the number of steps taken as a measure of activity. This work examined the correlation of activity level between owner and pet dog and found that the more active the owner was, the more active the pet dog was. However, the pedometer devices lacked functionality as the device design did not account for behaviours such as walking through wet

grass, which caused some devices to malfunction. Furthermore, the devices measured only the number of steps taken, which did not take into consideration steps taken for different gaits. The pedometers underestimated steps taken during running bouts and overestimated steps during walking/trotting in large and medium dogs while underestimating steps taken in every gait in small sized dogs (Chan et al., 2005). Additionally, the devices could not measure static behaviours, such as posture, which limits the scope of usage. The devices also had a level of inaccuracy, which means that it could not be used in all studies. However, advancements in wearable technology have resulted in better devices which can measure activity and behaviour of animals with higher accuracy. The more advanced wearable technology (accelerometer) has been used on over 120 species of animals (Brown et al., 2013).

2.5.3 Accelerometry

Accelerometers are wearable devices that work by measuring acceleration (changing velocity rates) along one or multiple axes and quantifying events using epochs (sampling intervals), which can then be categorised into behaviours/motion states depending on the coding and algorithms involved (Watanabe et al., 2005; Hansen et al., 2007; Lascelles et al., 2007; Lascelles et al., 2008; Shepard et al., 2008; Brown et al., 2013). For the devices themselves, there are uniaxial, biaxial, and triaxial accelerometry methods and devices.

Uniaxial accelerometers measure acceleration along one axis and are most sensitive parallel to the longest side of the device, which is generally oriented along the cranio-caudal axis, corresponding to the z-axis as seen in Figure 2-1 (Hansen et al., 2007; Lascelles et al., 2007; Lascelles et al., 2008; Andrews, 2015). Biaxial accelerometers measure acceleration along two axes and may be a combination of two uniaxial accelerometers which measure the craniocaudal (front/back; z-axis) and dorsoventral (up/down; y-axis) axes separately (Watanabe

et al., 2005). Triaxial accelerometers measure acceleration along all three axes, which achieves measurements in a three-dimensional plane (Smit et al., 2023). The resulting measurements from acceleration data can be used in cats and dogs to infer activity (Hansen et al., 2007; Lascelles et al., 2007; Lascelles et al., 2008; Yam et al., 2011; Preston et al., 2012; Deng et al., 2014; Andrews et al., 2015; Gruen et al., 2017; Mejia et al., 2019) and behaviour (Den Uijl et al., 2017; Wernimont et al., 2018; Muñana et al., 2020; Yamazaki et al., 2020; Galea et al., 2021; Smit et al., 2023; Liu, 2024; Redmond et al., 2024; Smit et al., 2024; Smit et al., 2025). Devices can be placed on collars or on a harness, depending on the study (see Figure 2-1 and 2-2).

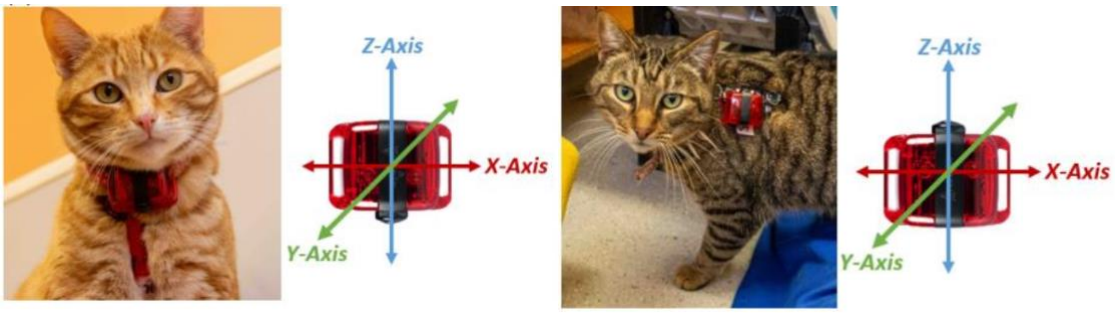


Figure 2-1. Placement and orientation of ActiGraph accelerometer on a cat collar (left) and harness (right). *From Smit et al. (2023)*



Figure 2-2. Size of ActiGraph accelerometer (left) mounted on dog collar (right). *From Redmond et al. (2024)*

2.5.4 Accelerometry for Measuring Activity

Acceleration data have been compared with observed activity and shown to be correlated (Hansen et al., 2007; Lascelles et al., 2007; Lascelles et al., 2008; Andrews et al., 2015). For example, Lascelles et al. (2008) and Andrews et al. (2015) used omnidirectional accelerometers to quantify overall activity in colony housed cats. Other cat studies have measured activity, such as with pain relief in cats suffering from joint pain (Lascelles et al., 2007; Gruen et al., 2017), to monitor ovarian activity (Andrews et al., 2022), around feeding time (Deng et al., 2014), and as a metric of sleep quality (Yamazaki et al., 2020). In dogs, accelerometers have been used to measure activity, to determine spontaneous activity (Hansen et al., 2007), to determine habitual activity (Yam et al., 2011), on a treadmill (Preston et al., 2012), in subjects suffering from joint pain (Mejia et al., 2019), and in a colony setting (Hoffman et al., 2019).

The accelerometer that many studies have used to measure activity is the Actical "minimitter" device (Hansen et al., 2007; Lascelles et al., 2007; Lascelles et al., 2008; Deng et al., 2014; Andrews et al., 2015; Gruen et al., 2017; Mejia et al., 2019; Andrews et al., 2022). This device measures acceleration in three dimensions for an epoch that is set by the researcher (Andrews et al., 2015) from 15 second to 1 minute increments (Hansen et al., 2007; Gruen et al., 2017). The data is processed directly onboard the device using associated software which sums the total acceleration/movement over the defined epoch, and produces one value known as an "activity count" as a metric of activity (Deng et al., 2014). The data is already processed, but the output does not give researchers detailed information on the axes that were measured. Thus, this device is useful for overall activity comparisons but is not a good metric for behaviour. To obtain more detailed information, more comprehensive data loggers that provide raw acceleration data, like the ActiGraph, are now more widely used.

2.5.5 Behavioural Classification and Machine Learning

Accelerometer data compared with observed behaviour of animals was shown to be correlated in both cats (Watanabe et al., 2005; Galea et al., 2021; Smit et al., 2023; Liu, 2024) and dogs (Wernimont et al., 2018; Redmond et al., 2024). For example, Watanabe et al. (2005) found that accelerometry measuring the craniocaudal (front/back) and dorsoventral (up/down) axes could reliably detect behaviours like eating, drinking, and grooming by inferring posture using the acceleration from gravity. Modern devices collect triaxial acceleration along three independent axes: x, y, and z.

Tools that are used in conjunction with accelerometry are machine/deep learning algorithms, which are used to correlate expressed behaviours with accelerometer data (Smit et al., 2023). Machine learning (ML) models have been developed for feral cats (Kestler and Wilson, 2015), free-roaming pet cats (Galea et al., 2021), colony cats (Smit et al., 2023), colony dogs (Redmond et al., 2024), and even to detect activity and emotional patterns of dogs (Aich et al., 2019). Developed models only work for specific collar placements (collar/harness mounted accelerometers) (Smit et al., 2024), so it is vital to match the model with the mounting location (but collar mounted is most common). Deep learning models are also a viable option, but are still in the process of being developed (Mozumder et al., 2024). Accelerometry is commonly used with machine learning for behaviour expression approximation and may be used in conjunction with positional data like GPS, physiological data like heart rate sensors, environmental data like humidity (Brown et al., 2013), or gyroscopes and magnetometers (Aich et al., 2019) to possibly enhance accuracy and detail or obtain different data.

Most accelerometers used to measure behaviour are triaxial accelerometers such as the ActiGraph (Smit et al., 2023; Liu, 2024; Redmond et al., 2024; Smit et al., 2024; Smit et al.,

2025). The ActiGraph can be collar and harness mounted (Smit et al., 2023), and records acceleration data in all three axes (see Figure 2-1). Raw acceleration data (or acceleration data across the three axes) are exported (Smit et al., 2023) and summarised in short epochs (1s) to smooth the data, which are used to derive and calculate 32 identifier variables including the mean/sum/max/min/sd accelerations, skewness, kurtosis, correlation, vector magnitude, and overall dynamic body acceleration (ODBA) (Smit et al., 2023; Liu, 2024; Redmond et al., 2024). This data can then be used to train ML models, which are then used to evaluate behaviour. Published studies in dogs have notably used a wide variety of triaxial accelerometers such as the Vetrax, Sweet Solution, PetDialog+, and the Whistle Activity Monitor (see Table 2-4). These other devices mostly seem to directly process the raw triaxial acceleration data onboard into behaviours of interest (Den Uijl et al., 2017; Wernimont et al., 2018; Hoffman et al., 2019; Muñana et al., 2020), much like the Actical "minimitter" device.

Table 2-4. Summary of accelerometer devices used in reviewed literature

Accelerometer	Axes measured	Species	Publications
Actical	Omnidirectional	Humans, cats, dogs	Hansen et al. (2007); Lascelles et al. (2007); Lascelles et al. (2008); Deng et al. (2014); Andrews et al. (2015); Gruen et al. (2017); Mejia et al. (2019); Yamazaki et al. (2020); Andrews et al. (2022)
ActiGraph	Triaxial	Cats, dogs	Yam et al. (2011); Smit et al. (2023); Liu (2024); Redmond et al. (2024); Smit et al. (2024); Smit et al. (2025)
ADXL202E	Biaxial	Cat	Watanabe et al. (2005)
Axivity AX3	Triaxial	Cats	Galea et al. (2021)
Heyrex	Triaxial	Dogs	Mejia et al. (2019)
PetDialog+	Triaxial	Dogs	Den Uijl et al. (2017)
Plus Cycle	Triaxial	Cats	Yamazaki et al. (2020)
Whistle Activity Monitor	Triaxial	Dogs	Muñana et al. (2020)
Vetrax	Triaxial	Dogs	Wernimont et al. (2018)
VetSens	Triaxial	Dogs	Hoffman et al. (2019)
Other (non-commercial)	Triaxial	Badger, cormorant, turtle, shark, penguin, cheetah, coypu, tapir, anteater, guanaco, armadillo, mouflon, llama, dogs	Shepard et al. (2008); Aich et al. (2019)

2.5.6 Current Applications

Relevant studies estimating pet behaviour using accelerometers that output raw acceleration data and ML models have focused on exhibited behaviours of pets in free roaming (Watanabe et al., 2005; Galea et al., 2021), and colony settings (Smit et al., 2023; Liu, 2024; Redmond et al., 2024), and indoor settings (Smit et al., 2024) (see Table 2-5).

Table 2-5. List of studies quantifying behaviour in cats or dogs in different settings using raw accelerometry data

Reference	Species	Mounting location	Setting
Watanabe et al., 2005	Cat	Collar	Free roaming
Galea et al., 2021	Cat	Harness	Free roaming
Smit et al., 2023	Cat	Collar + harness	Colony
Liu, 2024	Cat	Collar	Colony
Redmond et al., 2024	Dog	Collar	Colony
Smit et al., 2024	Cat	Collar	Free roaming + Indoor
Smit et al., 2025	Cat	Collar	Colony

Watanabe et al. (2005) and Galea et al. (2021) quantified behaviours of free roaming cats. Watanabe et al. (2005) used a canonical discriminant analysis (CDA) and spectral analysis to distinguish behaviours and frequencies of behaviours in a single cat while Galea et al. (2021) used self-organising maps (SOMs) and random forest (RF) models. Smit et al. (2023) and Liu (2024) quantified behaviours of colony cats using SOM and RF models. Behaviours such as locomotion (walk/trot), eating, grooming, littering, lying, scratching, sitting, and standing were quantified. These are the remaining behaviours quantified by the ML model after combining or excluding from the original list of behaviours due to inaccuracies, low frequency, or confusion by the ML models (Smit et al., 2023; Smit et al., 2024; Smit et al., 2025).

Redmond et al. (2024) examined behaviours of dogs using an accelerometer that outputted raw acceleration data. This study quantified behaviours of dogs in the colony setting using RF models. Previously referenced studies of activity and behaviour in dogs mostly used devices that directly processed output accelerations into behaviours, so are not as relevant to this study.

2.6 Human-Animal Interaction

2.6.1 Bonding

Relationships with pets can exist as psychological bonds and physical bonds (Ines et al., 2021), which cats and dogs share with humans. According to Ines et al. (2021), the psychological bond refers to when the pet and human have a shared purpose, common interest, or affection/emotions. Attachment is a psychological bond cats and dogs share with humans and involves a strong emotional connection (Ines et al., 2021). Vitale et al. (2019) categorised attachment styles of cats into secure, insecure-ambivalent, and insecure-avoidant. They suggested that once established, the attachment style likely remains stable, and found that indicators of attachment such as proximity seeking, separation distress, and reunion behaviour, were consistent with the description of attachment relationships. Dog-human relationships were also recognised to involve strong attachment bonds (Payne et al., 2015), and can be categorised into classifications such as secure, insecure-avoidant, insecure-ambivalent, and insecure-disorganised/disoriented (Solomon et al., 2019). For dogs, these bonds may be naturally elicited through traits such as affection, loyalty, devotion, and physical interactions (Serpell, 2017). A strong attachment bond is supported by unconditional affection from the dog (Serpell, 2017), minimising the probability of the owner's actions jeopardising the relationship. The implication is that even when the bond is under threat due to actions of the owner, the dog will still provide affection, helping to maintain the bond. The bond dogs have with humans can clearly be described as attachment, but findings from the strange situation test have been less consistent in cats (Palmer and Custance, 2008). The strange situation test that the cats did not pass involved episodes where the pet is exposed to either the owner or a stranger doing tasks in its vicinity in a

test room (Ines et al., 2021; Pongrácz et al., 2025), and has a counterbalanced version (Ines et al., 2021) which reversed the order of episodes in the test (Palmer and Custance, 2008).

The physical bond in house pets refers to when the pet is physically restricted from leaving and hence must adapt to life in a home setting (Ines et al., 2021). The degree of association with the pet likely influences the bond with humans (Case, 2003; Vitale, 2022; Egaña-Marcos et al., 2025). Case (2003) attributed the diversity of human-cat relationships to whether they are feral, free-roaming/loosely owned, or house cats. Feral cats have little to no contact with humans (Case, 2003), free-roaming/loosely owned cats have some degree of contact (Vitale, 2022), and house cats are nearly or completely indoors (Case, 2003). The potential for socialisation and formation of cat-human bonds involving feral and free-roaming/loosely owned cats depends on their tolerance to touch, and in-depth studies of human-cat bonds have mainly focused on house cats since the bond should be the strongest in a setting where they will have the most association (Case, 2003). This idea that the status of the animal influences bonding likely holds true for dogs, and potentially other pets, because socialisation and formation of bonds strengthens with time spent together (Egaña-Marcos et al., 2025).

The influence of humans affects bonding with both cats and dogs (Turner and Bateson, 2014; Bao and Schreer, 2016; Vitale and Udell, 2019; Leech et al., 2022; Egaña-Marcos et al., 2025). Turner and Bateson (2014) determined that the relationship between cats and humans is a two-way process by examining the interaction of owners and cats during feeding. They found that variations in expressed behaviours depended on the owner personality and the cat's sex. Furthermore, Leech et al. (2022) found that owner-animal preferences (referring to what pet species is preferred) and housing types could affect cat personality and behaviour. For example, the amount of attention humans give to cats can influence cat behaviour, increasing the amount

of time spent in the vicinity of humans with increasing amounts of attention given to the cat (Vitale et al., 2019). Bao and Schreer (2016), in an assessment of pet ownership and wellbeing, found that human personality also affects the bond with dogs, with variations in well-being metrics (e.g. life satisfaction, happiness, positive/negative emotions, neuroticism, suppression, relatedness, competence) mediated by differences in personality.

While examining the role of pets and owners in the bond, cats appear to have more influence on the relationship than dogs. More specifically, Turner (2021a) found that cats were more in control of social contact durations than the human, meaning that bonding depended on the cats' willingness to engage. On the contrary, the bond between humans and dogs seems to be more balanced overall, even to the point that behaviour and appearance mirrors that of each other (Bender et al., 2025), but favours humans through processes such as obedience training, behaviour correction training, and more (Koutsopoulos, 2024).

2.6.2 Benefits for Humans

Studies of human-animal interactions have examined how the health of humans were affected by pet ownership (McCune et al., 2014). Friedmann et al. (1980) found that humans with pets had a higher survival rate when discharged from a coronary heart unit than humans without pets, showing that ownership of a pet had the potential to increase survivability. In a recent review of human-animal interaction literature, Gee and Wells (2025) stated that the psychological effects of animals on humans included modifying anxiety, loneliness, satisfaction, happiness, and self-esteem in a positive way. They also mentioned physical benefits such as improved stress management, fitness, blood pressure, and changes in oxytocin release. Overall, human-animal interaction was associated with a range of benefits to human health, and animal-assisted therapy utilising these benefits has become more widespread (Gee and Wells, 2025).

Although there are published benefits, the full literature is inconsistent (Gee and Wells, 2025). Herzog (2011) stated that pets were a potential source of injury and death, diseases, and conflict between neighbours, and could not fully demonstrate the psychological benefit of pets to humans due to an inability to replicate results. For example, loneliness was shown to remain unaltered even after acquiring a pet (Gilbey et al., 2007), increased attachment to pets was associated with higher levels of depression (Miltiades and Shearer, 2011), and a lower well-being was reported amongst pet owners during the COVID-19 pandemic (Amiot et al., 2022). Inconsistency may be due to a lack of standardised methods for researching human-animal interaction, reliance on owner reports, and other possible research biases (Herzog, 2011).

Comparing published impacts of pet ownership between cat and dog owners, the literature appears to suggest that dogs have an overall higher positive impact on humans compared to cats. In a study examining pet ownership and wellbeing, Bao and Schreer (2016) found that the wellbeing of dog owners was higher than that of cat owners in many metrics, which were replicated in a study of well-being of pet owners during the COVID-19 pandemic (Amiot et al., 2022). Data varied depending on the owner personality (Bao and Schreer, 2016), gender, and socioeconomic status, so there are other factors to consider (Amiot et al., 2022).

2.6.3 Benefits for Animals

Having a strong human-animal bond physically and psychologically may also benefit both cats and dogs (Tan et al., 2020; Foreman-Worsley et al., 2021; de Abreu Oliveira et al., 2023). Foreman-Worsley et al. (2021) stated that many owners chose to keep cats indoors out of consideration for the safety of the cat. Access to the outdoors poses a risk to cats because they may suffer trauma (cars, dogs, wildlife, other cats), be accidentally poisoned, are more likely to be infected with parasites and diseases (Tan et al., 2020), and may even become pregnant (de

Abreu Oliveira et al., 2023). Dogs also suffer an increased risk to be infected with diseases outdoors (Serpell, 2017), and likely have further physical risks. So, a strong human-animal bond serves to benefit both cats and dogs physically.

Psychologically, people believe access to the outdoors is good for the mental health of the cat (Tan et al., 2020), while there is a lack of literature regarding dogs. However, natural behaviours and psychological benefits can be achieved indoors using enrichment as seen in shelter cats (Parthasarathy, 2025), and in kennel dogs with enrichment and training (Wells, 2004; Herron et al., 2014). Environmental enrichment strategies include modifications or additions to the environment to promote physical and psychological stimulation (Nelagonda et al., 2025), and social contact (see Table 2-6). Cat and dog enrichment strategies seem to differ in focus with cat enrichment strategies focused more on environmental additions while dog enrichment strategies focused more on interaction with other animals and humans. These differences could potentially be due to the different degree of evolution and socialisation the two species have had with humans.

Table 2-6. Summary of example enrichment in cats and dogs

Source	Species	Enrichment	Description
da Silva Gonçalves et al. (2025)	Cat	Scratching Post	Anything designed for cat scratching behaviour
		High places	Access to high places
		Hiding places	Access to hiding places
		Access to toys	Access to toys
		Play interaction	Interaction between owner and cat
		Cat massage brush	Brush to massage cat
		Cat water fountain	Place to drink flowing water
		Cat grass	Grass for cat nibble or play with
		Leashed cat walk	Access to outdoors via leashed walk
		Balcony w/ cat net	Access to see outside, but no direct access outdoors
		Top of walls/gates	Access to top of walls/gates
		Catnip	Plant that elicits response from some cats
		Play w/ other animals	Opportunity for contact with other animals (cats, dogs, both)
		Food puzzle	Puzzle feeder that requires effort for food
Turner and Bateson (2014)	Cat	Dietary	Wet or dry feed types
Wells (2004)	Dog	Conspecific contact	Social contact with other dogs
		Human contact	Social contact with humans
		Toys	Access to dog toys
		Cage furniture	Furniture for increased verticality and line of sight
		Music	Auditory stimulation
		Odor	Olfactory stimulation
Herron et al. (2014)	Dog	Puzzle feeder	Feeder that requires effort for food
		Behaviour training	Obedience training
Hunt et al. (2022)	Dog	Playhouse	Playhouse with tunnels, slides, and platforms
		Tug play	Handler plays tug of war and fetch with dog
Serpell (2017)	Dog	Outdoor runs	Access to outdoors with handler
		Chews	Items for dog to chew on

2.6.4 Problem Behaviours

While there are some benefits of keeping animals in the home, there are also some drawbacks. Literature on human-animal interactions have examined problem behaviours, or behaviours that are a nuisance to humans, and attempted to prevent them (Gazzano et al., 2008; Turner and Bateson, 2014; Gazzano et al., 2015; Didehban et al., 2020; Tynes, 2025). Some common problem behaviours of cats and dogs are described in Table 2-7. Problem behaviours in both cats and dogs are similar, with house soiling, destructiveness, and aggression studied in both animals. In terms of prevention, the effectiveness of advice from veterinary behaviourists for kitten and puppy owners was studied and found to lead to informed owners and decreased problem behaviours (Gazzano et al., 2008; Gazzano et al., 2015).

Table 2-7. Summary of example problem behaviours of cats and dogs

Source	Species	Behaviour	Description
Turner and Bateson (2014)	Cat	House soiling	Defecates/urinates in inappropriate places
		Territorial aggression	Aggression when new cat introduced
		Fear-related aggression	Defensive aggression, arched back, piloerection
		Inter-cat aggression	Aggression between cats, mostly in males
		Play-related aggression	Hunting behaviour directed at owner
		Redirected aggression	Aggression towards surrounding after seeing aggressive cats
		Petting-evoked aggression	Acts of aggression during petting
		Eating grass/plants	Consuming grass/plants
Didehban et al. (2020)	Dog	Excessive activity	Dog moves constantly, and has bouts of energy
		Fearfulness	Afraid in many contexts
		Destructiveness	Tendency to destroy dog bed, blanket, clothes
		Roaming	Movement around the home and tendency to go outdoors
		House soiling	Defecates/urinates in inappropriate places
		Withdrawal	Soulless and quiet
		Aggression towards familiar people	Mild to severe aggression towards familiar people
		Aggression towards unfamiliar people	Mild to severe aggression towards unfamiliar people
		Aggression towards dogs	Mild to severe aggression towards dogs
		Aggression towards owner	Mild to severe aggression towards owner
		Excessive barking	Barking too much
		Mounting and humping	Dog mounting and humping behaviour expression
		Coprophagy	Dog consumes own or other animal's faeces
Tynes (2025)	Cat	Destructive scratching/chewing	Destruction of property via scratching/chewing

2.6.5 Gaps in Literature

For companion-animal behaviours, studies have focused on problem behaviours that become issues in the home or veterinary environments (McKeown and Luescher, 1988; Gazzano et al., 2008; Voith, 2009; Turner and Bateson, 2014; Gazzano et al., 2015; Wassink-van der Schot et al., 2016; Didehban et al., 2020; Tynes, 2025). Studies of the effect of human-animal interaction on behaviour and health have largely examined only the proposed benefits for humans (Barker and Wolen, 2008; Friedmann and Son, 2009; McCune et al., 2014; Artemiou et al., 2021; Gee and Wells, 2025). However, there is little literature on the effects of human-animal interaction on the companion animals themselves, as opposed to literature on domesticated farm animals such as poultry, pigs, and cattle (Hemsworth et al., 1994; Rushen et al., 2001; Zulkifli, 2013). This means that the impact of human-animal interaction on the behavioural expression and welfare of cats and dogs remain largely unexplored.

2.7 Stress

Stress levels, or heightened responses to cope with the environment, are a common indicator for welfare of cats and dogs (Bradshaw et al., 2012; Serpell, 2017). This can be visualised using behavioural expression and physiological measurements. Behavioural indicators of stress in cats could be a decrease of certain behaviours (general, maintenance, play), and in increase in others (hiding, defensive aggression, fighting) (Rochlitz, 2005; Bradshaw et al., 2012). Dogs may also respond to stressors by displaying stereotypies such as repetitive behaviour and increased grooming (Serpell, 2017).

Stress responses can be measured through changes in blood pressure, heart rate, respiratory rate, which are non-specific (Rochlitz, 2005; Turner and Bateson, 2014; Serpell,

2017). More specific measurements record activity of the hypothalamic-pituitary-adrenal (HPA) axis and glucocorticoid levels (e.g. cortisol), which Ahmed et al. (2023) reports as a key indicator of stress. However, these required more invasive assessments (e.g. blood draws), which affected results (Rochlitz, 2005; Turner and Bateson, 2014), and could only be applicable for short-term/acute measurements.

A less invasive method for measuring stress responses is to measure faecal glucocorticoid metabolite (FGM) concentrations, which works well in tracking changes in FGM concentrations in cats and dogs over longer periods of time (Schatz and Palme, 2001). FGMs are the digested versions of cortisol, and measurement usually involves drying and grinding faecal samples, extracting the FGM, and determining the concentration using an assay such as an enzyme immuno-assay (EIA), which has been possible in birds (Gholib et al., 2018), cats (Kusuda et al., 2022), and dogs (Schatz and Palme, 2001). Limitations include no current standardized methods, which leads to uncertain precision and accuracies of results. For example, Kusuda et al. (2022) noted an inter-assay variation of 10.1%.

2.8 Justification and Objectives

The previous studies in cats and dogs have focused on exhibited behaviours in different environments and situations and have not taken into consideration the effect of direct human presence and the impact of their interactions, so more study is required. These studies provide a baseline which may be used to examine effects of human interaction on the behaviour and welfare of colony cats and dogs, which may potentially translate into the household setting.

Objectives of the thesis are as follows:

1. Determine if changes in human-animal interaction duration and frequency have significant effects on activity levels and behavioural expression of cats and dogs

2. If there are effects, determine direction of changes of behavioural expression in cats and dogs.

3. Determine how changes in human-animal interaction duration and frequency affects the faecal glucocorticoid metabolite concentrations of cats and dogs

Chapter 3. Impact of Human-Animal Interaction on Feline Activity, Behaviour, and Stress









3.1 Introduction

Cats and humans influence each other in many ways (Turner and Bateson, 2014) through interaction, known as human-animal interaction. Studies of the effect of human-animal interaction on behaviour and health have largely examined only the proposed benefits for humans, (Barker and Wolen, 2008; Friedmann and Son, 2009; McCune et al., 2014; Artemiou et al., 2021; Gee and Wells, 2025). In contrast, studies of cats have focused on behaviours in different situations and environments (Liu, 2024; Smit et al., 2024; Smit et al., 2025), rather than the influence of direct human presence and impact of interactions. As such, this study quantified how activity, behaviour, and stress was impacted due to human-animal interactions using previously validated or adapted methods and models in cats (Kusuda et al., 2022; Smit et al., 2023).

3.2 Materials and Methods

The study was conducted at the Massey University Centre for Feline Nutrition, Palmerston North, New Zealand (40°23'25.2"S, 175°36'56.8"E) between the 1st of October and 28th of October 2025. This study was approved by the Massey University Animal Ethics Committee (MUAEC 25/41).

3.2.1 Animals and Housing

This study included 16 healthy (11 male, 5 female) domestic shorthair cats aged 3.13 to 14.96 (mean ± SD; 7.61 ± 3.34) and weighing 2.74kg to 5.91kg (average weight ± SD; 5.58 ± 2.65; see Table 3-1). Throughout all periods of this study, cats were maintained under their normal colony management. They were housed in semi-outdoor colony cages, fed a standard complete and balanced canned diet (Kraft Heinz Wattie's Ltd., Hastings, New Zealand), had *ad*

libitum water, and had normal weekly weighing/playtime sessions (Wednesday 1000-1200h) with the employees of the Feline Unit. The pens in this study were cleaned, the litter was replaced each day, and the cats were fed between 0730h and 0900h each day.

Table 3-1. General cat information including the group, cat, sex, neuter status, approximate age, average weight, and if they were removed from the study

Group	Cat	Sex (M/F)	Neuter Status (N/E)	Age (years)	Average Bodyweight (kg ± 1g)	Removed From Study Post Hoc
Control	Dalu	M	N	14.96	3.701	
	Kauri	M	N	7.55	5.353	
	Manuka	M	N	7.56	5.558	
	Noir*	F	E	3.13	2.803	X
	Quint*	M	N	3.68	3.613	X
	Sarah	F	N	9.87	2.808	
	Sugar	M	N	7.73	4.883	
	Zelda	F	N	10.61	3.959	
Treatment	Atticus	M	N	5.79	4.460	
	Covid	M	N	5.52	4.037	
	Dobby	M	N	6.64	5.688	
	Helix	M	N	4.62	5.858	
	Jed	M	N	13.86	2.974	
	Jube	F	N	7.73	2.922	
	Peanut	F	N	4.96	4.315	
	Totara	M	N	7.54	5.104	

*Removed due to incomplete baseline or uncertain data (explained in Chapter 3.2.2)

3.2.2 Experimental Design

The study was comprised of three study periods (see Table 3-2): habituation/baseline (week 1), treatment (weeks 2/3), and observation (week 4). At the start of the habituation/baseline period, accelerometers (ActiGraph wGT3X-BT, 19 g, 33 mm×46 mm×15 mm; ActiGraph, Pensacola, FL, USA) were attached to collars. The devices were positioned

ventrally on the neck of the cats with the orientation of axes as shown (see Figure 3-1). The devices were initialised using the proprietary software, ActiLife (version 6.13.6; ActiGraph, Pensacola, FL, USA), at a 30 Hz sampling frequency (dynamic range of ±8g), with sleep enabled, and set to start at 8AM on the 1st and 15th of October 2025. All 16 cats were habituated to wearing data loggers and baseline data collection was conducted simultaneously to assess for inclusion in the study. This period lasted one week, since cats already wear collars under normal colony management. Inclusion in the data analysis was retrospectively assessed according to the reliability of data (less than 5 total instances where collar fell off and needed refitting) and if more than 85% of the baseline period was completed successfully. Quint was removed from data analysis due to the number of times he lost his collar (23 times total), and Noir was removed from data analysis due to incomplete baseline data. So, the final set of animals included in the study was 14 cats (6 in control group, 8 in treatment group; 9 male, 5 female; age 7.87 ± 3.28 years; weight 5.72 ± 2.69kg).

Table 3-2. Cat study timeline

Day	Date	Period	Manipulation
D-7	1-Oct-25	Habituation/Baseline Begins	Accelerometer collars on, normal weighing
D-6	2-Oct-25		Faecal sample collection 7-10 AM
D-5	3-Oct-25		
D-4	4-Oct-25		
D-3	5-Oct-25		
D-2	6-Oct-25		
D-1	7-Oct-25	Habituation/Baseline last day	Faecal sample collection 7-10AM
D0	8-Oct-25	Treatment period begins	Normal weighing
D1	9-Oct-25		Faecal sample collection 7-10AM
D2	10-Oct-25		Playtime 10-11AM
D3	11-Oct-25		
D4	12-Oct-25		
D5	13-Oct-25		Playtime 10-11AM
D6	14-Oct-25		Faecal sample collection 7-10AM
D7	15-Oct-25		Replace accelerometers, normal weighing
D8	16-Oct-25		Faecal sample collection 7-10AM
D9	17-Oct-25		Playtime 10-11AM
D10	18-Oct-25		
D11	19-Oct-25		
D12	20-Oct-25		Playtime 10-11AM
D13	21-Oct-25		Faecal sample collection 7-10AM
D14	22-Oct-25	Observation begins	Normal weighing
D15	23-Oct-25		Faecal sample collection 7-10AM
D16	24-Oct-25		
D17	25-Oct-25		
D18	26-Oct-25		
D19	27-Oct-25		
D20	28-Oct-25	Last day of trial	Final faecal sample collection 7-10AM
D21	29-Oct-25	Trial ends	Remove accelerometers



Figure 3-1. Cats and their accelerometer devices, with the orientation of axes

Manipulations of cats took place as indicated (see Table 3-2). During the habituation/baseline period (week 1), human interaction with the cats was limited to normal colony practice (some interaction during daily pen cleaning, weekly weighing/playtime). Following baseline, the cats were allocated into either the treatment (8 cats) or control (6 cats) groups, which was determined based on the number of cats that successfully completed baseline data collection. During the treatment period (weeks 2&3), two additional playtime sessions with the researcher were introduced on Monday and Friday 1000-1100h. During these sessions, the cats of the treatment group were offered additional direct interaction with the researcher. The cats interacted with the researcher, other cats, or with other environmental enrichment (running wheel, boxes, beds, scratchers, various small toys). The researcher ensured that each cat had at least 5 minutes direct contact with him during every session. For the observation period (week 4) the interactions returned to the levels in the habituation/baseline period to determine if there were any lasting effects of the treatment.

To compare faecal glucocorticoid metabolite (FGM) concentrations between groups, faecal sampling occurred twice a week on Tuesdays and Thursdays from 0700-1000h; one

sampling session following a day of additional human-animal interaction, and one sampling session following a day with no additional interaction. These sessions involved the researcher observing both pens of cats (treatment and control) simultaneously and collecting fresh faecal samples within 15 minutes of defecation. Information recorded included the cat, time the samples were collected, and the total weight of the faecal sample for identification. All the faeces produced during sampling were collected and used samples.

The collected faeces were labelled and put directly into a freezer kept at -80ºC, then transported to a different freezer and stored at -20ºC. The samples were freeze-dried starting on the 29th of October 2025 using a Cuddon FD80LT freeze dryer (Cuddon Ltd, Belnheim, New Zealand). After freeze drying, the samples were stored in freezers at -20ºC until grinding, which occurred on the 17th of March 2026. The ground samples were stored at -20 ºC freezers until extraction and analysis, which began on the 11th of June, and was completed on the 12th of June 2026.

3.2.3 Weather Data Collection and Analysis

Weather data was collected using a Vantage Pro2™ ISS weather station (Davis Instruments, Hayward, CA, USA) at the Centre for Feline Nutrition that was previously used in a longitudinal study on season and behaviour of domestic cats (Smit et al., 2025). The device computes hourly metrics including average temperature (ºC), minimum and maximum temperatures (ºC), total rainfall (mm), heat index (HI; ºC), and temperature-humidity-wind index (THW; ºC) (see Table 3-3). Heat and THW indexes (ºC) were included to reflect correlations between temperature, humidity, and wind (Smit et al., 2025).

Table 3-3. Units and definitions of weather variables. *From Smit et al. (2025)*

Variable	Unit	Definition
Temperature	ºC	Average temperature of an hour
Minimum temperature	ºC	Lowest temperature recorded in an hour
Maximum temperature	ºC	Highest temperature recorded in an hour
Rainfall	mm	Total rainfall in an hour
Heat index	ºC	Average temperature of an hour, considering temperature and humidity. How hot the air feels.
THW index	ºC	Average temperature of an hour, considering temperature, humidity, effects of sunshine and wind chill. How it feels under shade.

3.2.4 Behavioural Statistical Analyses

Raw acceleration data were downloaded from the accelerometers, exported using ActiLife (version 6.13.6; ActiGraph, Pensacola, FL, USA), then matched with metadata (collar name, times, dates). This combined data was then run through a previously developed machine learning (ML) model (Smit et al., 2023) using RStudio R version 4.4.0 and the 32 identifier variables (see Table 3-4), and then calculated and summarised into 1 second epochs. The model classified acceleration data into active (locomotion), inactive (lying, sitting, standing), and maintenance behaviours (eating, grooming, littering, scratching) and reported overall dynamic body acceleration (ODBA). ODBA was calculated as a sum per hour, while the other variables were recorded as minutes per hour. Full definitions of behaviours are as described in Table 3-5.

Table 3-4. ActiGraph identifier variables. *From Smit et al. (2023)*

Identifier Variable	Description
Mean	Mean, calculated for every second using the raw acceleration data (30 measures per second).
Sum	Sum, calculated for every second using the raw acceleration data. $Sum_{(Axis)} = \sum_{i=1}^{N} Axis_i$
Minimum (min)	Minimum value of every 30 measurements within each second.
Maximum (max)	Maximum value of every 30 measurements within each second
Standard deviation (sd)	Measurement of data spread
Skewness	Asymmetry of the distribution
Kurtosis	Weight of the tails relative to a normal distribution
Vector magnitude (VM)	$VM = \sqrt{X^2 + Y^2 + Z^2}$
Overall dynamic body acceleration (ODBA)	$ODBA = \sum_{i=1}^{N} \lvert DBA_X \rvert + \lvert DBA_Y \rvert + \lvert DBA_Z \rvert$
Dynamic body acceleration (DBA)*	$DBA = Sum_{(Axis)} - moving\ average$

*Not included as an identifier variable

Table 3-5. Ethogram of measured cat behaviours with definitions. *From Smit et al. (2023)*

Behaviour	Description
Active	Walking and trotting, involving forward movement
Eating	Cat ingests food by chewing and swallowing
Grooming	Cat cleans itself by licking, biting, or chewing fur on body. Also includes licking front paw and wiping head
Littering	Urination or defecation
Lying	Cat's body in contact with ground horizontally, including on the side, belly, or curled. Also includes crouch, lying, and sleeping.
Scratching	Cat scratches body with claws of hind feet
Sitting	Cat in upright position, hind legs flexed on the floor and front legs extended and straight
Standing	Cat in upright position and immobile, with all four paws extended and on the ground

Data were averaged across hours, and days. Hourly data, specifically periods before collars were observed to have fallen off the cat, were evaluated and removed if the researcher confirmed that the collar had fallen off. Tables were generated at a group-level for reporting. The results of observed ODBA and each behaviour were presented as weekly values. Weekly ODBA

was visualised using charts (total weekly average ± SE), and weekly behavioural expressions were visualised using proportions that sum to one within each week by treatment group. An independent t-test of means was conducted on general behaviour data (active, inactive, maintenance) after logit transformation of proportional data to see if there were differences between observed means of control and treatment groups.

Comparisons between groups were conducted to analyse if there were differences in activity and behaviour, between study periods and treatment groups. The analysis was conducted using generalised linear mixed models (GLMMs), which have been shown to work well for behavioural data when looking at external factors (Smit et al., 2025). The GLMMs were fitted using the 'glmmTMB' package (Brooks et al., 2017) in R (R studio, version 4.5.2) to examine the effect of the treatment during the periods of the study (baseline, treatment, or observation periods) on ODBA and behaviours. Results were considered significant if $P \leq 0.05$, and a trend if $0.05 < P \leq 0.10$.

ODBA was modelled using a Gamma distribution with a log link. The model included treatment group as a fixed effect and the individual animal as a random intercept to account for repeated measurements within individuals. The effect of treatment group and period on ODBA was tested using Wald χ^2 tests "joint_tests()" function from the emmeans package. If the joint test was found to be significant, pairwise comparison was conducted using the "pairs(emmeans())" function with no adjustment. Afterwards, the estimated means and 95% confidence intervals were determined using "emmeans (type = "response")". Then, R^2 values were printed, with conditional R^2 explaining the random effects of individual cats and the fixed effects of treatment group, and the marginal R^2 explaining only the fixed effect of treatment group.

The eight behaviours (active, eating, grooming, littering, lying, scratching, sitting, standing) were quantified as proportions by dividing the minutes spent expressing each behaviour by the total observation minutes per individual before GLMM analysis. They were quantified as proportions because there were unequal amounts of datapoints per animal after processing the data. The proportions were analysed using a zero-inflated beta GLMM using the glmmTMB package in R because the specific behaviours were continuously recorded and proportions are bounded between 0 and 1. A beta error distribution with a logit link function was used to model the data to avoid boundary issues and to assist linear modelling. For the output of each behaviour, model convergence and identifiability were assessed before interpreting the results. Outputs with large amounts of "NaN", or an output indicating that R could not produce a meaningful result for, were excluded from analysis with the GLMM.

An intercept-only zero inflation term ("ziformula = ~1") was included due to the repeated observations of zero due to the trial design. When a behaviour was not being expressed at a certain time (e.g. littering, eating) it was recorded as a zero value, which is highly unlikely in normal statistics and needed to be considered.

The effect of treatment group and study period on behaviours was individually tested using Wald χ^2 tests "joint_tests" function from the emmeans package to find significant differences in behaviours. If the value was found to be significant, the estimated means and 95% confidence intervals were found using "emmeans (type = "response")" from the same package and a pairwise comparison was conducted using the "pairs(emmeans())" function. Pairwise contrasts within-group were reported using superscripts, between-group contrasts were reported as P values, and both were described in text. The P-values of pairwise contrasts were not adjusted from the log-odds scale. Then, R^2 values were printed, with conditional R^2 explaining the

random effects of individual cats and fixed effect of treatment, and the marginal R^2 explaining the fixed effect of treatment on the specific behaviour.

3.2.5 Faecal Glucocorticoid Metabolite Analysis

Faecal glucocorticoid metabolite (FGM) extraction was conducted following a methanol extraction process described by Kusuda et al. (2022). Cat faecal powder (0.1 g) was extracted with 5 mL of 80% methanol (diluted with MilliQ water). The mixture was vortex-mixed and shook on a plate shaker (IKA-VIBRAX-VXR) for 30 minutes, then left overnight at 4^{o}C. On the following day, the mixture was centrifuged at 2500 rpm for 10 minutes. The supernatant was transferred to a tube and diluted 1:20 with assay buffer before being assayed. FGM concentrations were measured on a single plate using a Cortisol ELISA Kit (ADI-900-071; Enzo Life Sciences, Inc., Farmingdale, USA) according to the product manual.

FGM concentrations were averaged weekly within groups, and standard errors were calculated for visualisation. Quantity of faeces produced was unable to be factored in. The data were assessed using the 'glmmTMB' package (Brooks et al., 2017) in R version 4.5.2 to examine the effect of the treatment during the periods of the study (baseline, treatment, or observation periods) on faecal cortisol concentrations.

FGM concentrations were modelled using a GLMM with a gaussian distribution, which was similar to the method used to model FGMs in mountain goats (Dulude-de Broin et al., 2019), but allowed for interpretation of non-normal data. The model included treatment group as a fixed effect and the individual animal as a random intercept to account for repeated measurements within individuals. The effect of treatment and period on weekly faecal cortisol concentration was tested using Wald χ^2 tests "joint_tests()" function from the emmeans package.

If the value was found to be significant, a pairwise comparison was conducted using the "pairs(emmeans())" function with no adjustment to determine which periods and groups had differences. Afterwards, the estimated means and 95% confidence intervals were found using "emmeans (type = "response")". R^2 values were printed, with conditional R^2 explaining the random effects of individual cats and fixed effects of treatment, and the marginal R^2 explaining the fixed effect of treatment on the specific behaviour. Results were considered significant if $p \leq 0.05$, and a trend if $0.05 < p \leq 0.10$.

3.3 Results

3.3.1 Weather Data

During the study, daily temperatures ranged between 3.1 and 21.7°C with an average of 13.52 ± 0.38°C (mean ± SEM) across the whole study. Total daily rainfall (mm) ranged between 0 and 25.8 mm with an average of 4.04 ± 1.14mm (mean ± SEM). The daily heat index (HI), or what temperature the air felt like, ranged between 7.65 and 17.36°C with an average of 13.46 ± 0.40°C (mean ± SEM). The daily THW index, which is how the temperature felt under shade, ranged between 7.39 and 17.36°C with an average of 13.36 ±1.23°C (mean ± SEM). See Figure 3-2 for the full values across the study.

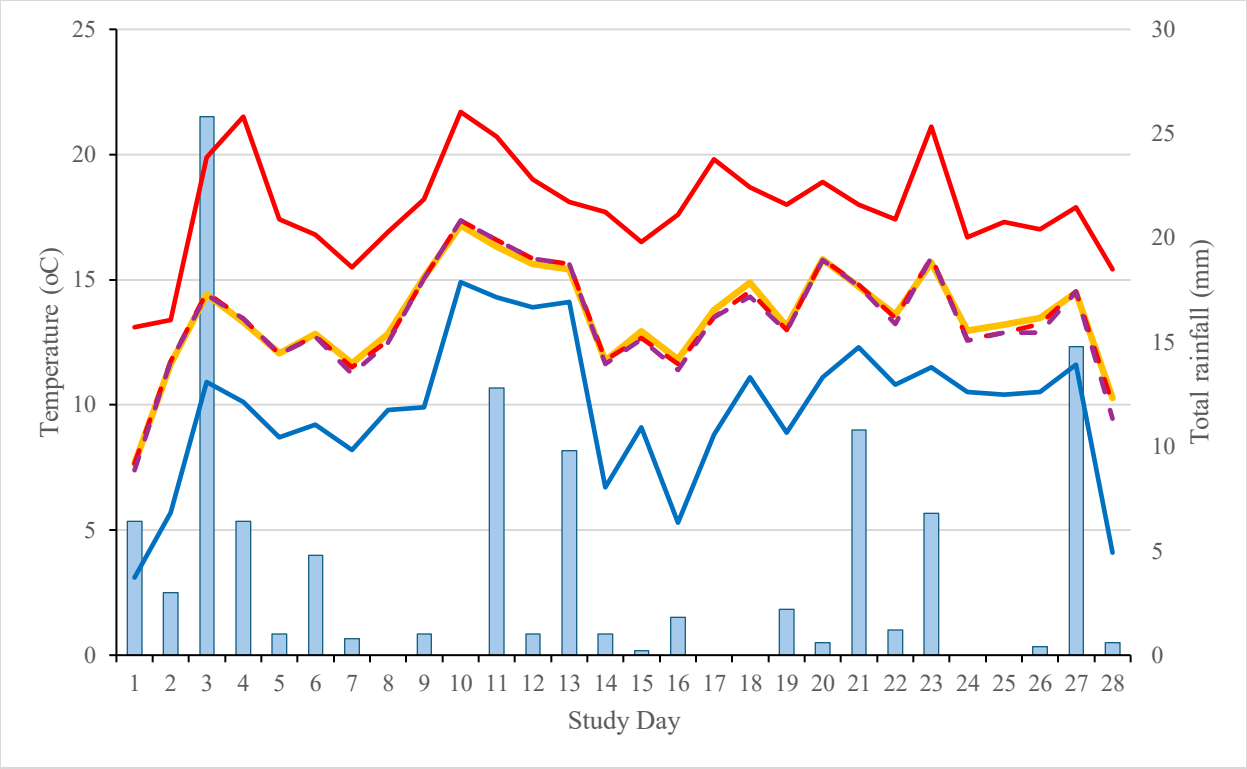


Figure 3-2. Daily temperature data/index (°C) and total rainfall (mm) data including total rainfall (light blue bar), average temperatures (solid orange line), maximum temperatures (solid red line), minimum temperatures (solid blue line), average heat index (dashed red line), and average THW index (dashed purple line) across the entire study

3.3.2 Overall Observed Activity and Behaviour

The study generated a total of 560459.53 useable minutes (389 days, 4 hours, 59 minutes, and 32 seconds) of data which was used for analysis. Total weekly observed average ODBA with SEM per week are shown in Figure 3-3.

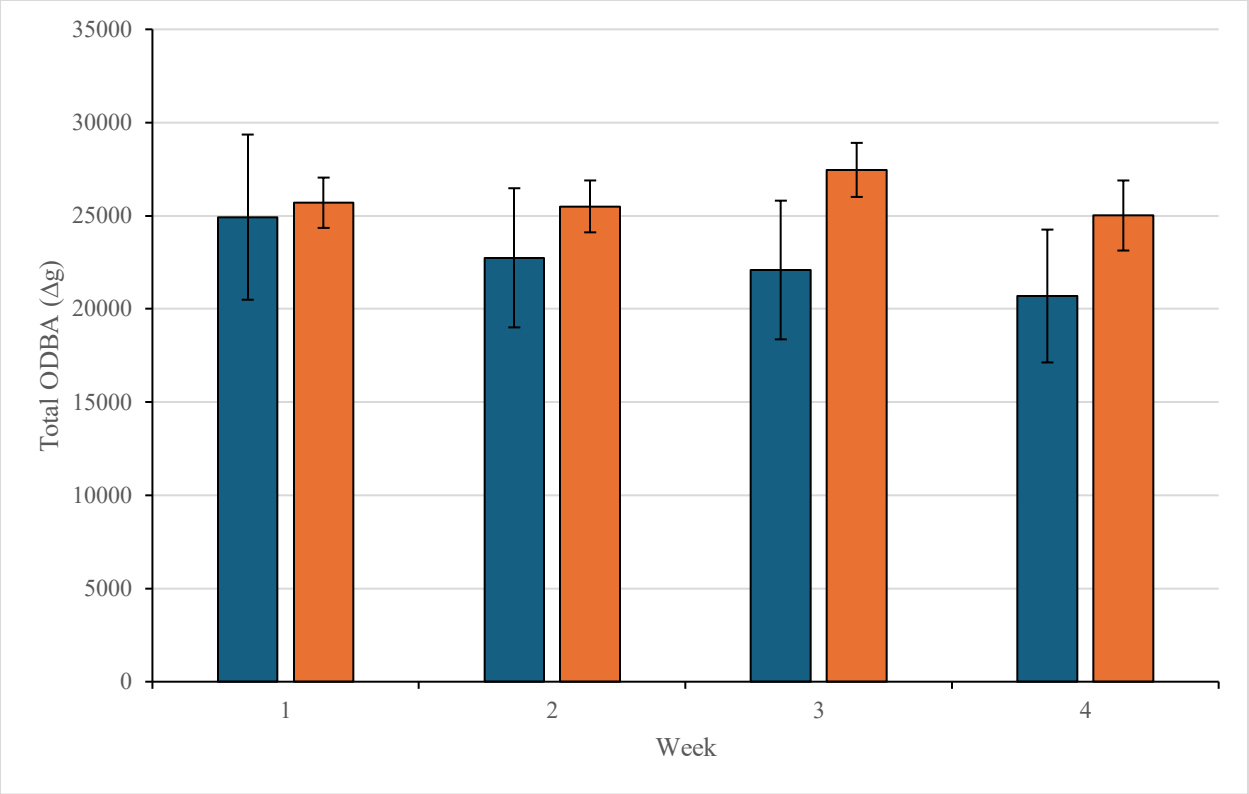
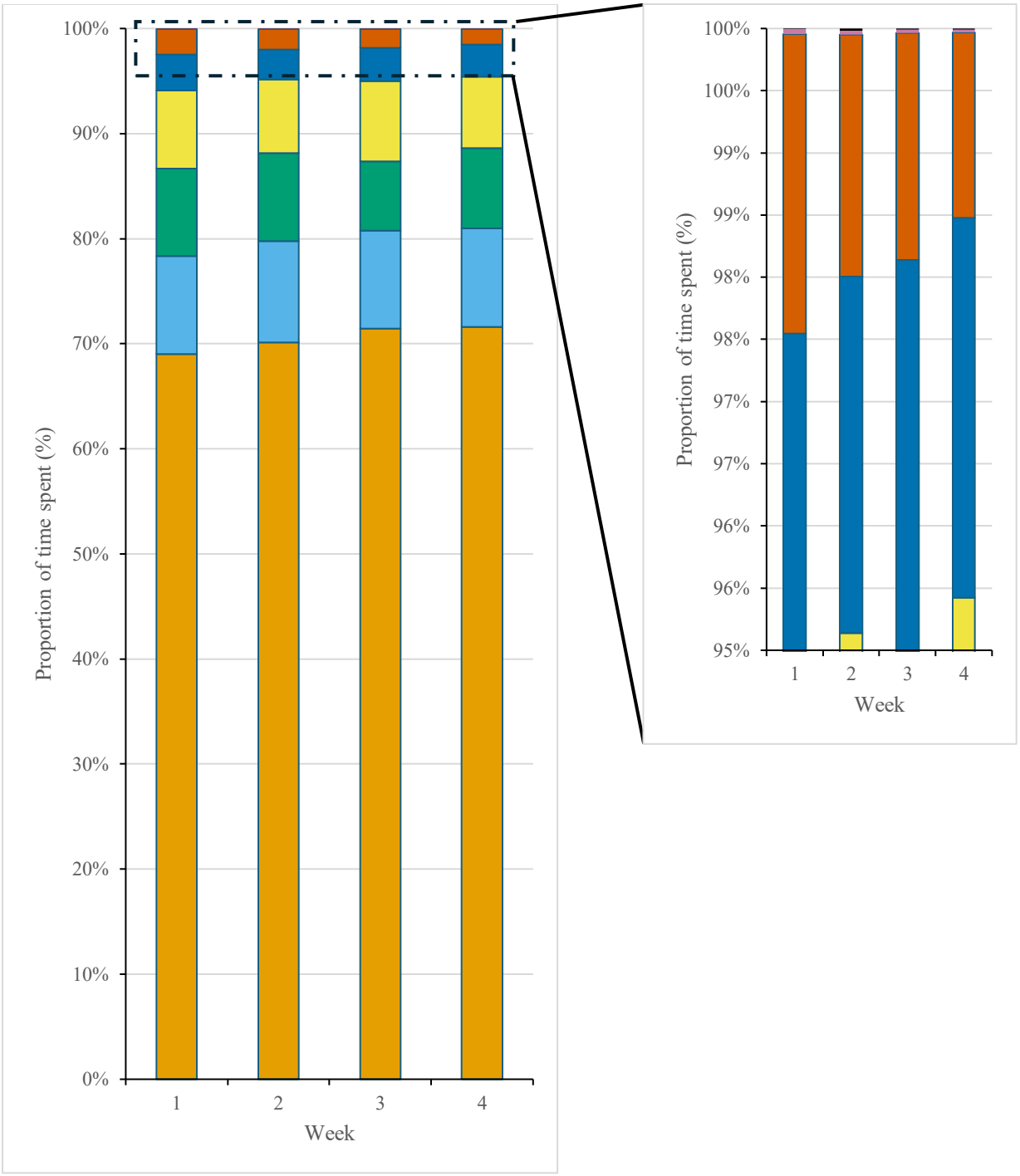
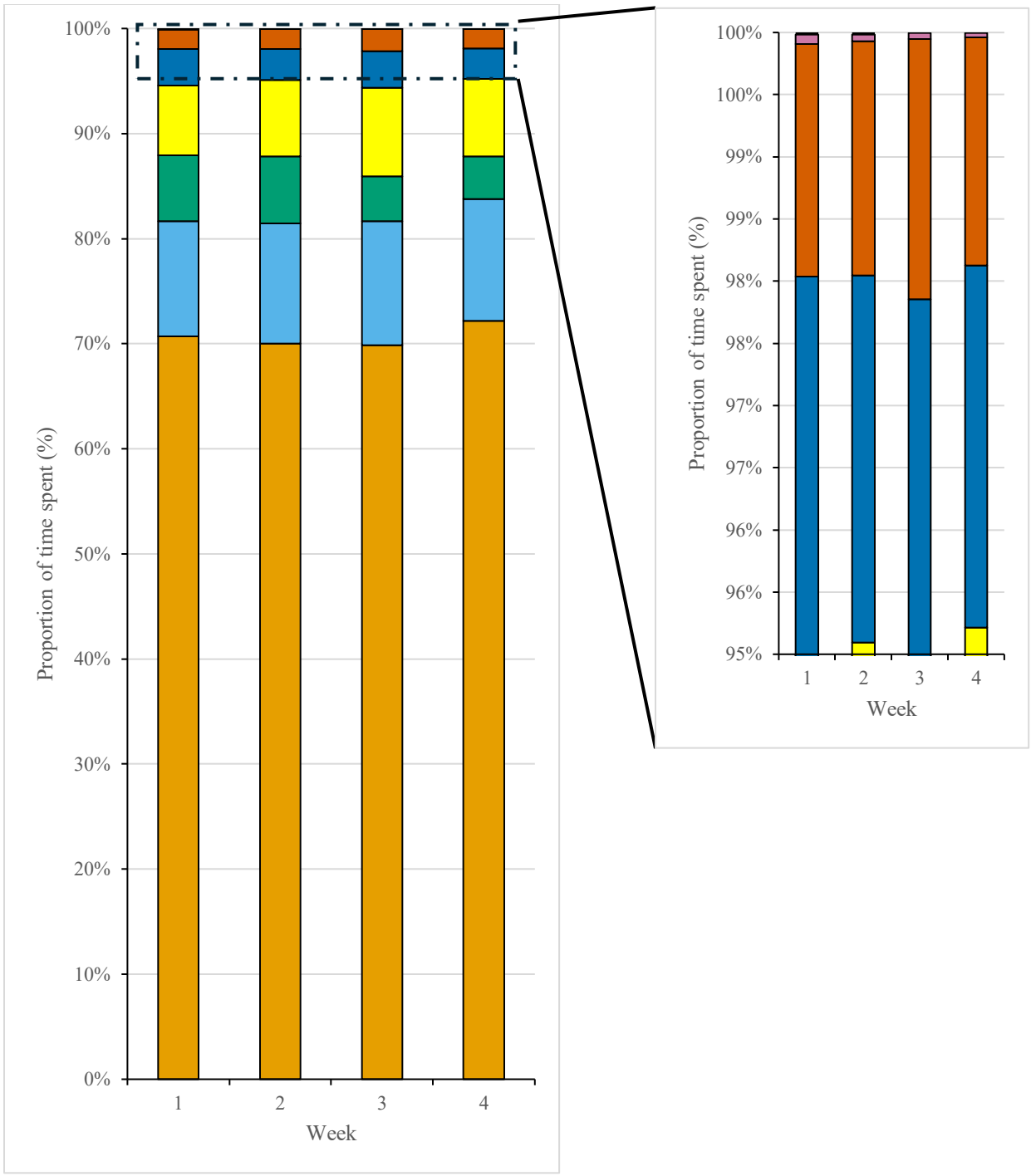


Figure 3-3. Total weekly average cat overall dynamic body acceleration (ODBA; mean ± SEM) of the control group (6 cats, blue bar) and treatment group (8 cats, orange bar). Total ODBA was calculated by summing the weekly ODBA, averaging it per minute, then scaling it back to a week per group. Week 1 = baseline, week 2/3 = treatment, week 4 = observation

The weekly proportion of time spent on each behaviour roughly conformed to the following time budget from most to least prevalent behaviour: lying > eating > sitting > standing > grooming > locomotion > scratching > littering. Weekly cat behaviour proportions are shown in Figure 3-4).


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Proportion of time spent (%)
1
2
3
4
Week
100%
100%
99%
99%
98%
98%
97%
97%
96%
96%
95%
Proportion of time spent (%)
1
2
3
4
Week

(a)



(b)

Figure 3-4. Weekly cat behaviour proportions as a percentage among the (a) control and (b) treatment groups. Behaviours represented include; lying (orange), eating (sky blue), sitting (bluish green), standing (yellow), grooming (blue), locomotion (vermillion), scratching (reddish purple), and littering (black). Week 1 = baseline, Week 2/3 = treatment, Week 4 = observation

Observed active, inactive, and maintenance behaviour independent t-tests of means showed no significant differences between control and treatment in the corresponding study periods for any of the broader behavioural categories. See Table 3-6 for full means, SEM, and P-values.

Table 3-6. Mean observed proportions (%) with SEM of the broad behaviour categories between control and treatment groups. P-values indicate significant differences between groups with: NS = not significant at $\alpha = 0.05$; MS = marginally significant at $0.05 < \alpha < 0.10$

Behaviour	Period	Control Group Mean	Treatment Group Mean	P-value
Active	Baseline	2.4±0.8	1.9±0.2	NS
	Treatment	1.9±0.5	2.0±0.2	NS
	Observation	1.4±0.4	1.8±0.2	NS
Inactive	Baseline	84.8±1.8	83.6±0.8	NS
	Treatment	85.6±1.7	83.1±0.9	NS
	Observation	85.6±1.9	83.6±1.1	NS
Maintenance	Baseline	12.8±1.2	14.5±0.8	NS
	Treatment	12.5±1.3	14.9±0.8	NS
	Observation	13.0±1.6	14.5±1.0	NS

3.3.3 Comparison of Treatment Group and Study Period

Differences of overall dynamic body acceleration (ODBA) between groups or periods as indicated by the joint test (P=0.002) are shown in Table 3-7. Pairwise comparisons in the control group revealed that ODBA during the baseline period was significantly higher than during the treatment (P=0.019) and observation (P<0.001) periods. ODBA also tended to be lower during the observation period than the treatment period (P=0.058).

Table 3-7. ODBA with 95% confidence intervals from the GLMM model on the response scale. Within a column, a different superscript indicates significant differences within the group; within a row, P-value indicates differences between the groups for the specific period: NS = not significant at $\alpha = 0.05$; MS = marginally significant at $0.05 < \alpha < 0.10$

Study Period	Control Group Means	Treatment Group Means	P-value
Baseline	22,759[a] (17,827-29,055)	25,509[A] (20,646-31,517)	NS
Treatment	20,713[b] (16,294-26,331)	26,229[A] (21,307-32,288)	NS
Observation	19,260[†b] (15,102-24,562)	24,618[†A] (19,925-30,417)	NS

[†]Marginal difference between control group treatment and observation periods

Within the treatment group, ODBA tended to be lower during the observation period compared to the baseline period (P=0.087) and treatment period (P=0.068). No differences between treatment and control groups in corresponding periods were detected. Fixed effects of treatment accounted for 12.4% of the variance (marginal R^2=0.124), while the full model, including random effects, accounted for 94% of the variance (conditional R^2=0.940).

For analysed behaviours, no significant differences were identified between groups or periods, as indicated by the joint test, for eating, grooming, littering, lying, sitting, and standing behaviours (see Table 3-8), so no further analysis was conducted.

Table 3-8. P-values of joint tests on treatment group and study period on weekly cat behaviour. NS = not significant at $\alpha = 0.05$; MS = marginally significant at $0.05 < \alpha < 0.10$

Behaviour	P-value
Locomotion	**<0.001**
Eating	NS
Grooming	NS
Littering	NS
Lying	NS
Scratching	**<0.001**
Sitting	NS
Standing	NS

Locomotion behaviour differences between groups or periods as indicated by the joint test (P<0.001) are presented in Table 3-9. Pairwise comparisons indicated significantly higher

locomotion behaviour in the control group during the baseline period compared to during the treatment (P=0.004) and observation periods (P<0.001). There was also a trend of higher locomotion behaviour in the treatment period than the observation period (P<0.001).

Table 3-9. Mean locomotive behaviour proportions (%) with 95% confidence intervals from the GLMM model on the response scale. Within a column, a different superscript indicates significant differences within the group; within a row, P-value indicates differences between the groups for the specific period: NS = not significant at $\alpha = 0.05$; MS = marginally significant at $0.05 < \alpha < 0.10$

Study Period	Control Group Means	Treatment Group Means	P-value
Baseline	2.04^{a} (1.32-3.14)	1.80^{A} (1.259-2.60)	NS
Treatment	1.49^{b} (0.96-2.29)	1.91^{A} (1.33-2.75)	NS
Observation	1.06^{c} (0.07-1.67)	1.77^{A} (1.21-2.57)	MS

Within the treatment group, no significant differences were detected. Between the two groups, pairwise comparisons showed only a trend of more locomotion behaviour during the observation period in the treatment group compared to the control group (P=0.088). Fixed effects of treatment accounted for 0.2% of the variance (marginal R^2=0.002), while the full model, including random effects, accounted for 1.9% of the variance (conditional R^2=0.019).

Scratching behaviour differences between groups or periods as indicated by the joint test (P<0.001) are shown in Table 3-10. Pairwise comparisons showed that in the control group, there was significantly more scratching during the baseline period compared to the treatment (P=0.013) and observation periods (P<0.001). Scratching also tended to be higher during the treatment period than the observation period (P=0.083).

Table 3-10. Mean scratching behaviour proportions (%) with 95% confidence intervals from the GLMM model on the response scale. Within a column, a different superscript indicates significant differences within the group; within a row, P-value indicates differences between the group for the specific period: NS = not significant at $\alpha = 0.05$; MS = marginally significant at $0.05 < \alpha < 0.10$

Study Period	Control Group Means (%)	Treatment Group Means (%)	P-value
Baseline	0.035^{a} (0.019-0.064)	0.051^{A} (0.031-0.085)	NS
Treatment	0.025^{b} (0.014-0.046)	0.036^{B} (0.022-0.060)	NS
Observation	$0.020^{\dagger b}$ (0.011-0.036)	0.025^{C} (0.015-0.042)	NS

†Marginal difference between control group treatment and observation periods

In the treatment group, scratching was significantly higher during the baseline period compared to during the treatment ($P<0.001$) and observation periods ($P<0.001$). There was also significantly more scratching in the treatment group during the treatment period compared to during the observation period ($P<0.001$). Between the treatment and control groups, there was a trend of more scratching in the treatment group during the observation period. No significant differences were detected between treatment groups during corresponding periods. Fixed effects of treatment accounted for 0.3% of the variance (marginal $R^2=0.003$), while the full model, including random effects, accounted for 2.1% of the variance (conditional $R^2=0.021$).

3.3.4 Faecal Glucocorticoid Data

A total of 44 cat faecal samples were collected, freeze-dried, ground, and run through the faecal cortisol ELISA. The sample sizes for each period are as seen in Table 3-11. Mean faecal glucocorticoid metabolite (FGM) concentrations with SEM are shown (see Figure 3-5).

Table 3-11. Total numbers of cat faecal samples collected from the control and treatment groups during each period of the study before being assayed using faecal cortisol ELISA

Group	Period	Total Samples
Control	Baseline	5
	Treatment	13
	Observation	5
Treatment	Baseline	3
	Treatment	12
	Observation	6

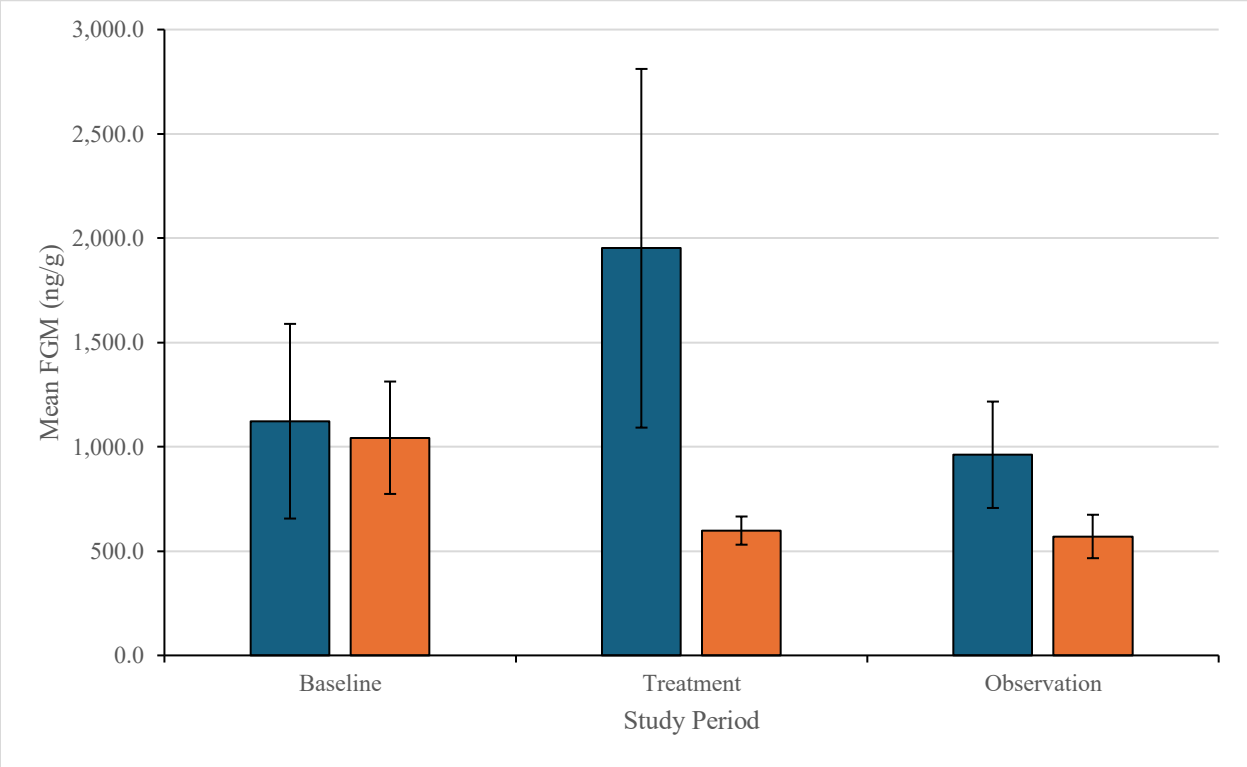


Figure 3-5. Mean observed faecal glucocorticoid metabolite (FGM) concentration (ng/g) with SEM for the control group (6 cats; blue bars) and treatment group (8 cats; orange bars) in the associated study period

FGM concentration differences as indicated by the joint test (P=0.039) are shown in Table 3-12. Pairwise comparison in the treatment group indicated that compared to the baseline period, FGMs tended to decrease during the treatment period (P=0.092), and were significantly lower during the observation period (P=0.012). There were no detectable differences within the

control group, nor between the control and treatment groups. Fixed effects of treatment accounted for 1.6% of the variance (marginal R^2=0.016), while the full model, including random effects, accounted for 98% of the variance (conditional R^2=0.980).

Table 3-12. Cat FGM concentration (ng/g) with 95% confidence intervals from the GLMM model on the response scale. Within a column, a different superscript indicates significant differences within the group; within a row, P-value indicates differences between the groups for the specific period: NS = not significant at $\alpha = 0.05$; MS = marginally significant at $0.05 < \alpha < 0.10$

Study Period	Control Group Means (ng/g)	Treatment Group Means (ng/g)	P-value
Baseline	1103^{a} (93.4-2113)	1884^{A} (801-2966)	NS
Treatment	1254^{a} (211.8-2295)	1363^{AB} (312.1-2415)	NS
Observation	1214^{a} (156.6-2271)	1162^{B} (134.5-2189)	NS

[†]Marginal difference between treatment group baseline and treatment periods

3.4 Discussion

This study aimed to examine whether changes of activity, behaviour, and FGM concentrations in cats occurred in response to additional human-animal interactions over a 4-week period in October 2025. This period corresponded to mid-spring at the study location (Centre for Feline Nutrition, Palmerston North, New Zealand). The findings showed significant differences in ODBA, locomotion behaviour, scratching behaviour and FGM levels in response to added human-animal interaction. The potential interaction between treatment group and study period was not examined as it was not part of the primary objectives. The analysis aimed to evaluate if there were overall effects of treatment group and study period on the behaviours using a combined variable that considered the treatment group and study period, which did not examine interaction of variables.

Additional human-animal interaction was associated with increased cat activity as measured by ODBA. The control group, which did not have additional interaction, showed

decreased activity between successive periods as the trial progressed. The treatment group, however, tended to decrease activity only between the treatment and observation periods. This suggests that the effect of additional human-animal interaction did not result in the decrease in activity as the trial progressed. As one of the first studies to quantify activity and behaviour of cats due to human-animal interaction, the mechanism behind the result is unclear. However, a possible explanation is decreased overall interaction with humans. During the trial, the cats were no longer allowed to be used for veterinary practicals and other trials, so the decreased activity levels as the trial progressed could be in part due to less overall interactions that they used to have. However, these findings could have been due to uncontrolled confounding variables. The results suggested that the added human-animal interaction in the treatment group offset the decreased activity levels seen in the control group significantly enough, resulting in only a marginal decrease during the observation period. Future studies should investigate how additional human-animal interaction would affect the activity of cats in a longer study.

The weekly time budget of behaviour proportions was similar to those reported in previous studies of cats in the same colony (Liu, 2024; Smit et al., 2025), indicating that the accelerometery and ML models determined a similar breakdown of behaviours as previous studies. There were no differences of means across treatment groups for active, inactive, and maintenance behavioural categories, indicating that on a broader scale, additional human-animal interaction did not result in differences between treatment and control.

Locomotion behaviour showed the same pattern as ODBA in response to additional human-animal interaction. Given that locomotion contributes to ODBA and includes trotting and walking behaviours (Smit et al., 2023), this finding was expected. The additional interaction consistently increased the locomotion of the treatment group compared to the control group. As

some of the cats preferred using the running wheel in the playroom, and they always explored the environment before engaging in human-animal interaction, an increase from 1 session per week to 3 sessions per week therefore increased the proportion of locomotion behaviour. This may have implications for the welfare of cats, as it is known that having higher activity levels can reduce the incidence of, and aid in weight loss in obese cats (Blanchard et al., 2025).

Scratching behaviour decreased throughout the trial in both control and treatment groups but tended to decrease between the treatment and observation periods within the control group. This suggests that increased human-animal interaction decreased scratching behaviour more consistently in the treatment group, even after the additional interactions had ended. This could imply both positive and negative welfare outcomes as the scratching behaviour measured in this study was a part of the maintenance behaviour of cats (see Table 2-3), which is also known as scratch grooming (Eckstein and Hart, 2000). Decreased scratching could indicate that the cat feels less of a need to groom after increased interactions with humans since some of the scratch grooming was provided by the researcher. It could also, however, indicate that the cat was decreasing its maintenance behaviour due to increased interactions, which may indicate a negative welfare state.

The observed cat faecal glucocorticoid metabolite (FGM) concentrations in this study were higher than concentrations measured in saliva (da Silva et al., 2017), much higher than concentrations measured using hair (Lamon et al., 2025), and comparable to blood plasma cortisol concentrations (Javadi et al., 2004). However, FGM doesn't measure cortisol directly as it measures metabolites from its breakdown instead, and is significantly correlated to other methods such as hair cortisol concentration (Accorsi et al., 2008). Therefore, it remains a useful tool to use for comparison of associated cortisol concentrations during a longer period. An

advantage of faecal sampling is the non-invasive quality, meaning no additional contact with the cats was required.

Added human-animal interaction appeared to decrease the faecal cortisol levels across the study within the treatment group This suggests that the human-animal interaction decreases the stress levels of the cats. However, the dataset was small, and the baseline for the treatment group only had three measurements, and the R^2 values suggested that most of the variation was from the random effects of individual cats. Further studies should be conducted to test the validity of faecal cortisol sampling, with emphasis on obtaining enough samples in colony cats, perhaps in conjunction with a treatment that is known to change the cortisol levels to test for validity.

3.5 Conclusion

This study aimed to examine changes in cat activity and behaviour when human-animal interaction in the form of playtime. This was done by utilising previously validated machine learning models in conjunction with collar-mounted ActiGraph accelerometer devices to quantify and analyse activity and behaviour. Although significant changes were detected in ODBA, locomotion behaviour, and scratching behaviour, it is not known how long the effects will persist for, and if these differences are able to be replicated as this is one of the first studies to examine interaction from the point of view of the cat and there were some confounding effects. Further study should be conducted to determine the longer-term effects of human-animal interactions on the behaviour of cats, considering the effects of more external factors and perhaps increasing the frequency of manipulations to better gauge the effects. The findings suggest possible increased welfare of the cats by lowering faecal cortisol levels. In addition, the study also demonstrated

that faecal cortisol analysis is a viable method for measuring and comparing non-acute cortisol levels adequately in cats but needs to be further explored.

Chapter 4. Impact of Human-Animal Interaction on Canine Activity, Behaviour, and Stress



4.1 Introduction

Dogs and humans influence each other in many ways such as through human-animal interactions (Bao and Schreer, 2016). Studies of the effect of human-animal interaction on behaviour and health have largely examined only the proposed benefits for humans, (Barker and Wolen, 2008; Friedmann and Son, 2009; McCune et al., 2014; Artemiou et al., 2021; Gee and Wells, 2025). In contrast, studies of dogs have focused on behaviours in different situations and environments (Redmond et al., 2024; Redmond et al., 2025) rather than the influence of direct human presence and impact of interactions. As such, this study quantified how activity, behaviour, and stress of dogs was impacted due to human-animal interactions using previously validated or adapted methods and models in cats (Kusuda et al., 2022; Redmond et al., 2024).

4.2 Materials and Methods

The study was conducted at the Massey University Centre for Canine Nutrition, Palmerston North, New Zealand (40°23'30.8"S, 175°36'56.3"E) between the 12th of November and 17th of December 2025. This study was approved by the Massey University Animal Ethics Committee (MUAEC 25/43).

4.2.1 Animals and Housing

The study included 8 healthy (6 male and 2 female) desexed working farm dogs and harrier hounds aged between 4.6 to 7.8 years (mean ± SD; 5.91±0.94) and weighing 21.0 kg to 35.5kg (mean ± SD; 26.75 ± 4.20; see Table 4-1). Throughout all periods of the study, dogs were under normal colony management. They were housed in semi-outdoor pens, fed a standard complete and balanced diet (BlackHawk Working Dog; Masterpet Ltd, Lower Hutt, New Zealand) according to the following formula, ME (kj) = 552 x kgBW$^{0.75}$(AAFCO, 2026), and

had *ad libitum* water available. The dogs in this trial had dispersed training sessions with Massey University professors and the unit manager. The pens in this study undergo cleaning between 0830h and 1000h daily, immediately after feeding.

Table 4-1. General dog information including the group, dog, sex, breed, approximate age, and average weight

Group	Dog	Sex (M/F)	Breed	Approximate Age (years)	Average Bodyweight (kg±1kg)
Group 1	Archy	M	Harrier hound	6.1	29
	Chloe	F	Harrier hound	6.0	23
	Lady	F	Heading dog	6.1	21
	Sam	M	Heading dog	6.1	27
Group 2	Gizmo	M	Harrier hound	7.8	30
	Lime	M	Harrier hound	4.6	26
	Link	M	Harrier hound	4.6	34
	Sooky	M	Heading dog	6.0	24

4.2.2 Experimental Design

This study followed a crossover design with three study periods (see Table 4-2): habituation/baseline (week 1), treatment/control 1 (weeks 2/3), treatment/control 2 (weeks 4/5). At the start of the habituation/baseline period, ActiGraph wGT3X-BT accelerometers (19 g; 33 mm×46 mm×15 mm) (ActiGraph, Pensacola, FL, USA) were attached to existing collars. The devices were positioned ventrally on the collar of the dogs with the orientation of axes as shown (see Figure 4-1). The devices were initialised using the associated software, ActiLife (version 6.13.6; ActiGraph, Pensacola, FL, USA), at a 30 Hz sampling frequency, with sleep enabled, and set to start at 0910h on the 12th and 0900h 26th of November 2025. All 8 dogs were habituated to wearing accelerometers and baseline data collection was conducted simultaneously to assess them for inclusion in the study. This period lasted one week, since the dogs already wear collars under normal colony management. Inclusion in data analysis was retrospectively assessed

according to the reliability of data (less than 5 total instances where collar fell off and needed refitting) and if more than 85% of the baseline was completed successfully. No collars/devices fell off during the baseline period, so all animals were included in the study.

Table 4-2. Dog study timeline

Day	Date	Period	Manipulation
-D7	12/11/25	Baseline/habituation	Accelerometer collars on
-D6	13/11/25		Faecal sampling
-D5	14/11/25		
-D4	15/11/25		
-D3	16/11/25		
-D2	17/11/25		
-D1	18/11/25		Faecal sample collection
D0	19/11/25	Treatment period 1: Group 1 treatment (4 dogs); Group 2 control (4 dogs)	Replace accelerometers
D1	20/11/25		Faecal sample collection
D2	21/11/25		Interaction time
D3	22/11/25		
D4	23/11/25		
D5	24/11/25		Interaction time
D6	25/11/25		Faecal sample collection
D7	26/11/25		
D8	27/11/25		Faecal sample collection
D9	28/11/25		Interaction time
D10	29/11/25		
D11	30/11/25		
D12	1/12/25		Interaction time
D13	2/12/25		Faecal sample collection
D14	3/12/25	Treatment period 2: Group 1 control (4 dogs); Group 2 treatment (4 dogs)	Replace accelerometers
D15	4/12/25		Faecal sample collection
D16	5/12/25		Interaction time
D17	6/12/25		
D18	7/12/25		
D19	8/12/25		Interaction time
D20	9/12/25		Faecal sample collection
D21	10/12/25		
D22	11/12/25		Faecal sample collection
D23	12/12/25		Interaction time
D24	13/12/25		
D25	14/12/25		
D26	15/12/25		Interaction time
D27	16/12/25	Last day of trial	Faecal sample collection
D28	17/12/25	Trial ends	Remove all collars



Figure 4-1. Dogs and their accelerometer devices, with the orientation of axes

Manipulations of the dogs took place as indicated (see Table 4-2). During the habituation/baseline period (week 1), human interaction with the dogs was only per normal colony practice (some interaction during daily feeding and walking to paddocks). During the treatment periods (week 2-4), there were an additional two structured playtime sessions with the researcher (Monday and Friday between 0900-1200h), for both group 1 (4 dogs, treatment then control period) and group 2 (4 dogs, control then treatment period). The crossover between control and treatment periods occurred between weeks 3 and 4. During the treatment sessions, the four dogs were each given 20-minute playtime/training sessions with the researcher one at a time. The dogs participated in activities such as interacting with the researcher and/or with the environment, which consisted of a grass paddock that had two dog kennels, a wooden platform, two water bowls, and half a barrel water bath. The following flowchart was followed for each session:

1. Bring the dog over to the empty paddock
2. Allow the dog to explore the area while the researcher just watches from inside the paddock

3. Attempt to train using the following series of commands: Sit → Down → Jump → Stay → Rollover
4. Allow the dog to disengage anytime, for paddock exploration or tactile contact

To compare faecal glucocorticoid metabolite (FGM) concentrations, faecal sample collection occurred twice a week on Tuesday and Thursdays at approximately 0830h, close to feeding time, as it was observed that fresh faeces were best collected within 10 minutes of eating. One session (Tuesday session) occurred following a day of additional human-animal interaction, and one session (Thursday) followed a day of no additional interaction. These sessions involved the researcher observing the pens as the dogs were being fed and collecting fresh faecal samples when possible. Some faecal samples were collected overnight if it was able to be distinguished between dogs (or if they were housed alone) or alternatively labelled as either of the dogs when they were unable to be confidently distinguished. Information recorded included the dog(s) and the sample date. Some but not all the faeces produced during (and before) sampling were collected and used samples.

The collected faeces were labelled and put directly into a freezer kept at -80^{o}C, then transported to a freezer and stored at -20^{o}C. The samples were freeze-dried starting on the 29th of October 2025 using a Cuddon FD80LT freeze dryer (Cuddon Ltd, Belnheim, New Zealand). After freeze drying, the samples were stored in freezers at -20^{o}C until grinding, which occurred on the 17th of March 2026. The ground samples were stored at -20 ^{o}C freezers until extraction and analysis, which began on the 11th of June, and was completed on the 12th of June 2026.

4.2.3 Weather Data Collection

Weather data was collected using a Vantage Pro2™ ISS weather station (Davis Instruments, Hayward, CA, USA) at the Centre for Feline Nutrition that was previously used in Chapter 3.1.3, which is roughly 100 metres away from the Centre for Canine Nutrition. The device computes hourly metrics including average temperature (°C), minimum and maximum temperatures (°C), total rainfall (mm), heat index (HI; °C), and temperature-humidity-wind index (THW; °C) (see Table 4-3). Heat and THW indexes (°C) were included to reflect correlations between temperature, humidity, and wind (Smit et al., 2025).

Table 4-3. Units and definitions of weather variables. *From Smit et al. (2025)*

Variable	Unit	Definition
Temperature	°C	Average temperature of an hour
Minimum temperature	°C	Lowest temperature recorded in an hour
Maximum temperature	°C	Highest temperature recorded in an hour
Rainfall	mm	Total rainfall in an hour
Heat index	°C	Average temperature of an hour, considering temperature and humidity. How hot the air feels.
THW index	°C	Average temperature of an hour, considering temperature, humidity, effects of sunshine and wind chill. How it feels under shade.

4.2.4 Behavioural Statistical Analysis

Raw acceleration data downloaded from the accelerometers went through the same process as in Chapter 3.1.4, but then was put through a previously developed machine learning (ML) model for colony dogs (Redmond et al., 2024) using RStudio R version 4.4.0 and the 32 identifier variables (see Table 4-4), and then summarised into 1 second epochs. The model classified acceleration data into active (barking, locomotion, sniffing), inactive (lateral recumbency, lying head down, lying head up, sitting, standing), and maintenance behaviours (eating, drinking, scratching), and reported overall dynamic body acceleration (ODBA). ODBA

was calculated as a sum per hour, while the other behaviours were recorded as minutes per hour. Full definitions of behaviours are as described in Table 4-5.

Table 4-4. ActiGraph identifier variables. *From Redmond et al. (2024)*

Identifier Variable	**Description**
Mean	Mean, calculated for every second using the raw acceleration data (30 measures per second).
Sum	Sum, calculated for every second using the raw acceleration data. $Sum_{(Axis)} = \sum_{i=1}^{N} Axis_i$
Minimum (min)	Minimum value of every 30 measurements within each second.
Maximum (max)	Maximum value of every 30 measurements within each second
Standard deviation (sd)	Measurement of data spread
Skewness	Asymmetry of the distribution
Kurtosis	Weight of the tails relative to a normal distribution
Vector magnitude (VM)	$VM = \sqrt{X^2 + Y^2 + Z^2}$
Overall dynamic body acceleration (ODBA)	$ODBA = \sum_{i=1}^{N} \lvert DBA_X \rvert + \lvert DBA_Y \rvert + \lvert DBA_Z \rvert$
Dynamic body acceleration (DBA)*	$DBA = Sum_{(Axis)} - moving\ average$

*Not included as an identifier variable

Table 4-5. Ethogram of measured dog behaviours with definitions. *From Redmond et al. (2024)*

Behaviour	Description
Barking	Mouth opened and closed quickly in snapping motion, with low frequency vocalisation
Drinking	Drinks water from bowl in paddock by lapping up water with tongue
Eating	Chews and ingests food from bowl provided
Locomotion	Walking, trotting, running, involving forward movement
Scratching	Grooming behaviour directed towards the body with paws
Sniffing	Nose directed to point of interest and sniffs
Lateral recumbency	Lying down flat on one side with head resting sideways on surface
Lying head-down	Lying on stomach with forelegs extended to the front, hind legs bent and close to body on each side, or body twisted and both hind legs on one side. Head lowered to rest on forelegs or ground between
Lying head-up	Lying on stomach with forelegs extended to the front, hind legs bent and close to body on each side, or body twisted and both hind legs on one side. Head is held up off the ground or surface
Sitting	Hind quarters on ground with front legs standing up straight
Standing	Dog in upright position and immobile, with all four paws extended and on the ground

Tables were generated at a group-level for reporting. The results of observed ODBA and each behaviour were presented as weekly values. Weekly ODBA was visualised using charts (total weekly average ± SE), and weekly behavioural expressions were visualised using proportions that sum to one within each week by treatment group. A paired t-test of means was conducted on general behaviour data (active, inactive, maintenance) after logit transformation of proportional data to determine if there were differences between observed means of control and treatment periods.

For data analysis, the generalised linear mixed model (GLMM) and associated R analyses were the same as in Chapter 3.2.4 but adapted for the specific dog behaviours processed by the model (barking, drinking, eating, lateral recumbency, locomotion, lying head down, lying head up, scratching, sitting, sniffing, standing). The GLMMs were fitted using the 'glmmTMB' package (Brooks et al., 2017) in R version 4.5.2 to examine the effect of treatment group and

study period (baseline, treatment/control 1, or treatment/control 2) on ODBA and behaviours. ODBA and the 11 dog behaviours analysed by the ML model was modelled the same way as in Chapter 3.2.4. The behaviours were quantified as proportions by dividing the minutes spent expressing each behaviour by the total observation minutes per individual for comparison with cats as proportions were used in Chapter 3.2.4.

Pairwise contrasts were also reported using superscripts and described in text. The P-values of pairwise contrasts were not adjusted from the log-odds scale. Then, R^2 values were printed, with conditional R^2 explaining the random effects of individual dogs and the fixed effect of treatment, and the marginal R^2 explaining the fixed effect of treatment on the specific behaviour. Results were considered significant if $P \leq 0.05$, and a trend if $0.05 < P \leq 0.10$.

4.2.5 Faecal Glucocorticoid Metabolite Analysis

Faecal glucocorticoid metabolite (FGM) extraction was done using the methanol extraction process previously described in Chapter 3.2.5 and assayed similarly except for 0.2 g of faecal powder used instead of 0.1 g, and dilution with assay buffer of 1:10 instead of 1:20 before being assayed. FGM concentrations were averaged weekly within groups and, and standard errors were calculated for visualisation. The data were assessed using the 'glmmTMB' package (Brooks et al., 2017) in R version 4.5.2 to examine the effect of the treatment during the periods of the study (baseline, treatment, or observation periods) on FGM concentrations in a similar manner as described in Chapter 3.2.5.

4.3 Results

4.3.1 Weather Data

During the study, daily temperatures ranged between 7.8 and 29.6ºC with an average of 17.95 ± 0.34ºC (mean ± SEM). Total daily rainfall (mm) ranged between 0 and 19.8 mm with an average of 2.30 ± 0.86mm (mean ± SEM). The daily heat index (HI), or what temperature the air felt like, ranged from 13.22 and 21.74ºC with an average of 17.99 ± 0.37ºC (mean ± SEM). The daily THW index, which is how the temperature felt under shade, ranged between 13.20 and 21.74ºC with an average of 17.96 ±0.38ºC (mean ± SEM). See Figure 4-2 for the full values across the study

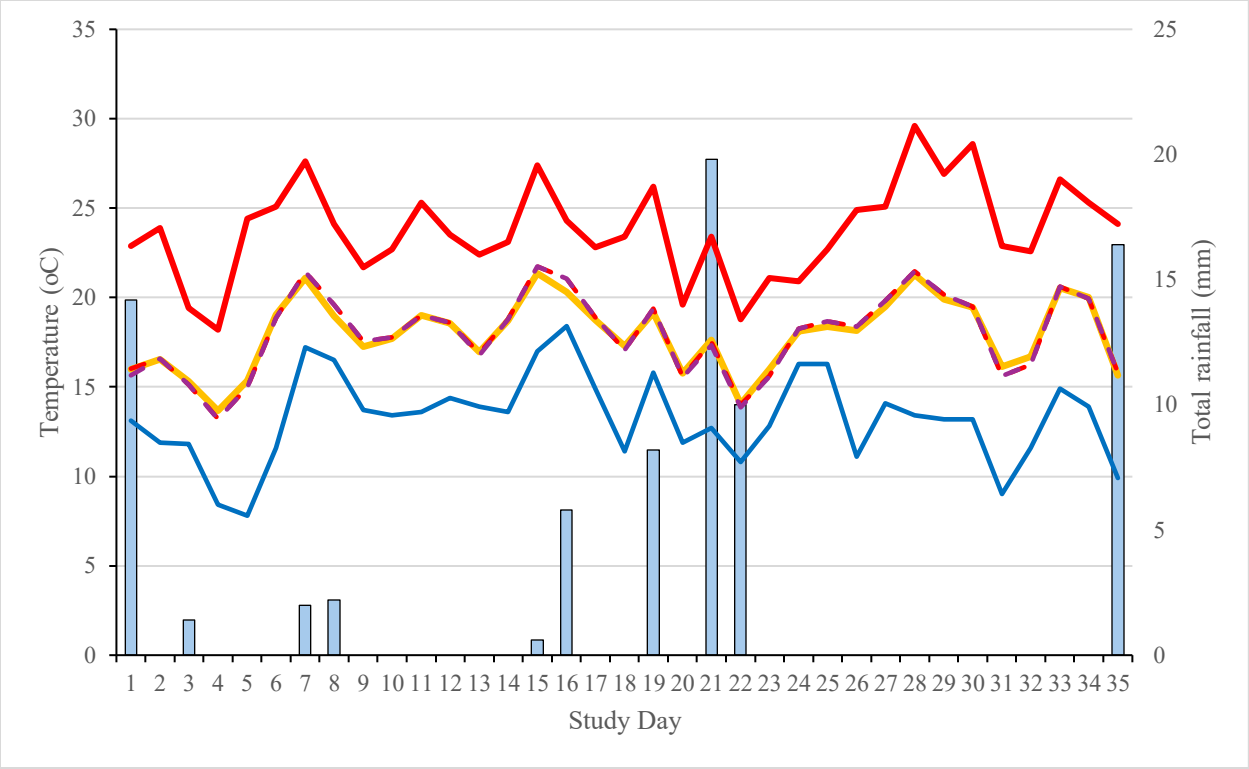


Figure 4-2. Daily temperature data/index (°C) and total rainfall (mm) data including total rainfall (light blue bar), average temperatures (solid orange line), maximum temperatures (solid red line), minimum temperatures (solid blue line), average heat index (dashed red line), and average THW index (dashed purple line) across the entire study

4.3.2 Overall Observed Activity and Behaviour

The sample dataset consisted of 402,160 useable minutes (279 days, 6 hours, and 40 minutes) of data which was used for analysis. Total weekly observed average ODBA with SEM are shown in Figure 4-3.

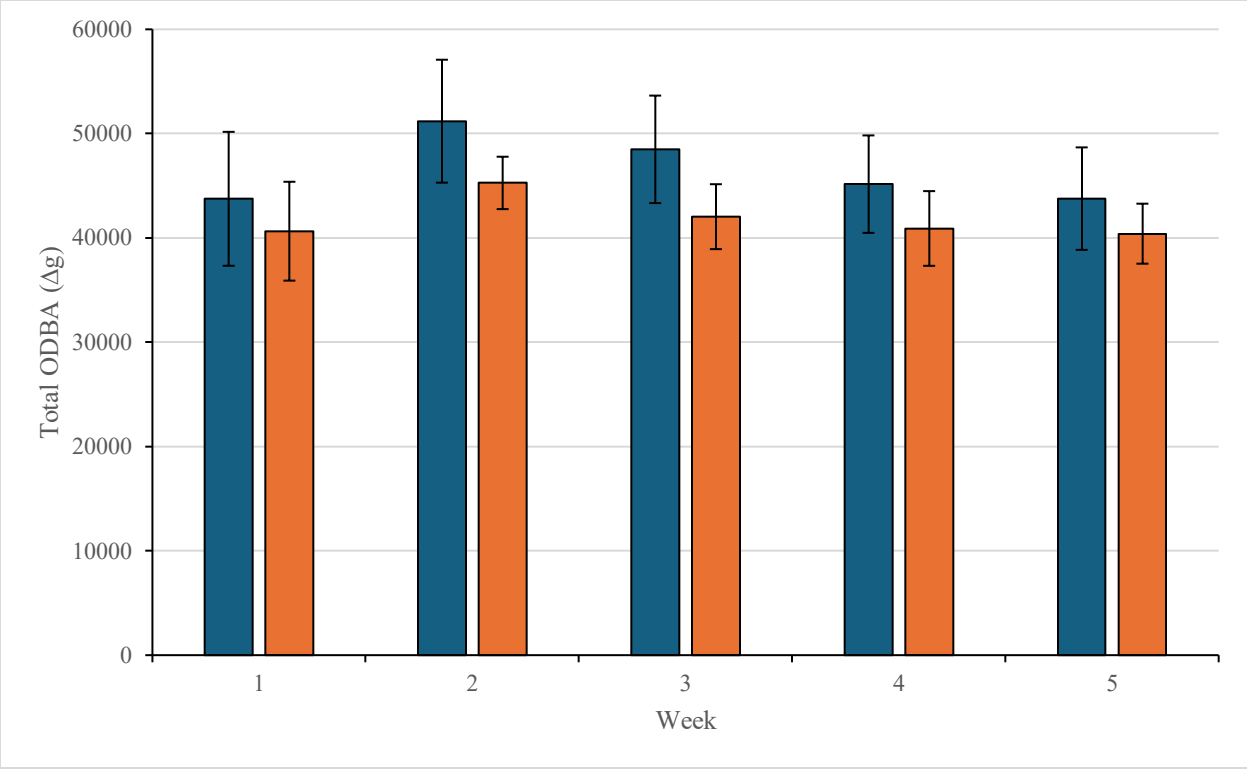
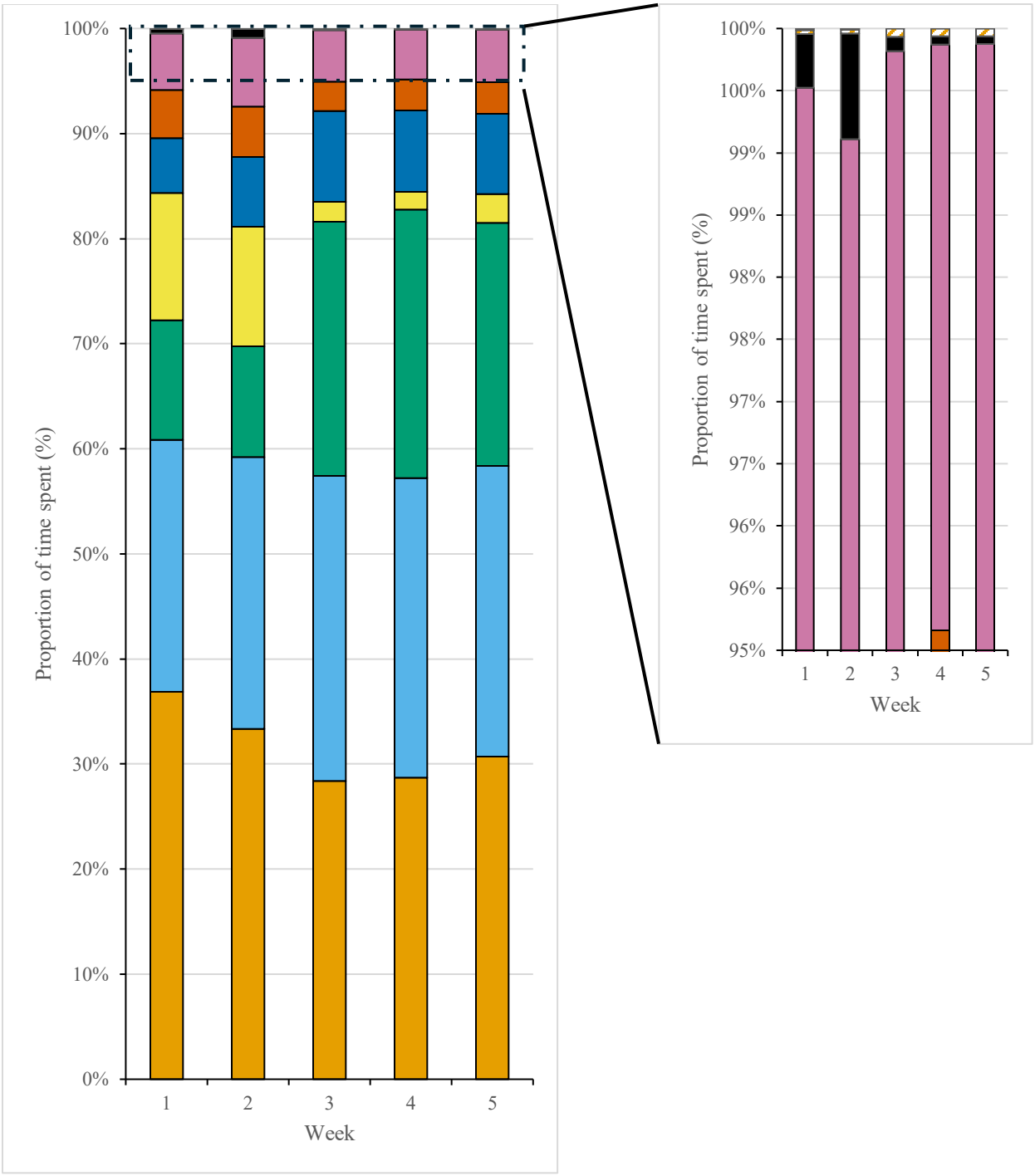
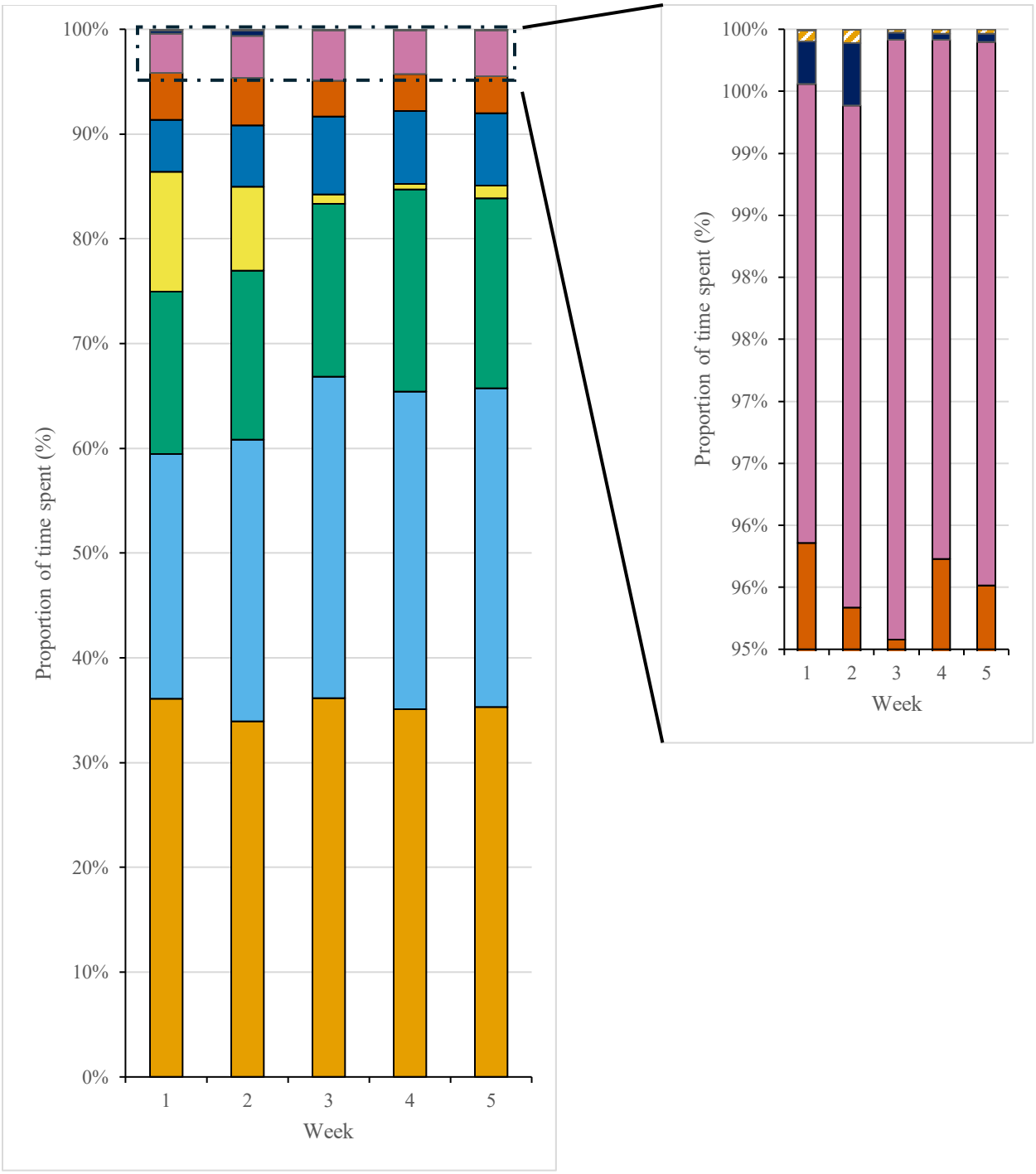


Figure 4-3. Total weekly average dog overall body dynamic acceleration (ODBA; mean ± SE) of group 1 (4 dogs, blue bars) and group 2 (4 dogs, orange bars) of dogs. Total ODBA was calculated by summing the weekly ODBA, averaging it per minute, then scaling it back to a week per group. Week 1 = baseline, week 2/3 = treatment/control 1, week 4/5 = treatment/control 2

The proportion of weekly time spent on each behaviour roughly conformed to the following time budget from most to least prevalent: lateral recumbency > lying head-up > barking > lying head-down/locomotion > sniffing/standing > sitting > scratching /eating /drinking. Weekly dog behaviour proportions are shown in Figure 4-4.


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Proportion of time spent (%)
1
2
3
4
5
Week
100%
100%
99%
99%
98%
98%
97%
97%
96%
96%
95%
Proportion of time spent (%)
1
2
3
4
5
Week

(a)



(b)

Figure 4-4. Weekly dog behaviour proportions among (a) group 1 and (b) group 2. Behaviours represented include; lateral recumbency (orange), lying head up (sky blue), barking (bluish green), lying head down (yellow), locomotion (blue), sniffing (vermillion), standing (reddish purple), sitting (black), scratching (orange with white diagonal stripes), eating (blue with black vertical stripes), drinking (bluish green with white diagonal stripes). Week 1 = baseline, week 2/3 = treatment/control 1, week 4/5 = treatment/control 2

Observed active, inactive, and maintenance behaviour paired t-tests of means revealed no significant differences between treatment and control periods of the crossover trial after combining the treatment and control periods of group 1 and 2. See Table 4-6 for full means, SEM confidence intervals, and P-values.

Table 4-6. Mean observed proportions (%) with SEM of the broad behaviour categories between treatment and control periods. P-values indicate significant differences of a t-test between means with: NS = not significant at $\alpha = 0.05$; MS = marginally significant at $0.05 < \alpha < 0.10$

Behaviour	Treatment Period Mean	Control Period Mean	P-value
Active	29.0 ± 3.3	31.0 ± 5.3	NS
Inactive	70.9 ± 3.3	69.0 ± 5.3	NS
Maintenance	0.00 ± 0.0	0.00 ± 0.0	NS

4.3.3 Comparison of Treatment Groups and Study Period

Differences in ODBA between groups or periods as indicated by the joint test ($P<0.001$) are shown in Table 4-7. Pairwise comparisons in group 1 (treatment then control period) showed that ODBA was higher during the treatment period than during the baseline ($P<0.001$) and control periods ($P<0.001$).

Table 4-7. ODBA with 95% confidence intervals from the GLMM model on the response scale. Within a column, a different superscript indicates significant differences within the group; within a row, P-value indicates differences between the groups for the specific period: NS = not significant at $\alpha = 0.05$; MS = marginally significant at $0.05 < \alpha < 0.10$

Study Period	Group 1 Means (treatment then control)	Group 2 Means (control then treatment)	P-value
Baseline	42,373^{a} (35,476-50,611)	39,957^{A} (33,453-47,726)	NS
Treatment (1)/Control (2)	48,915^{b} (41,115-58,195)	43,435^{B} (36,509-51,675)	NS
Control (1)/Treatment (2)	43,698^{a} (36,730-51,988)	40,329^{A} (33,898-47,980)	NS

In group 2 (control then treatment period), ODBA was higher during the control period than during the baseline ($P=0.011$) and treatment periods ($P=0.006$). There were no detectable differences between the treatment groups during any of the corresponding periods. Fixed effects

of treatment accounted for 12.8% of the variance (marginal R^2=0.128), while the full model, including random effects, accounted for 92.4% of the variance (conditional R^2=0.924).

For analysed behaviours, no significant differences were identified between groups or periods as indicated by the joint test for eating, lying head up, scratching, sitting, and standing behaviours (see Table 4-8), so no further analysis was conducted. Due to lack of or very low proportions of a behaviour during certain weeks, the drinking and lying head down behaviours could not be modelled using the GLMM.

Table 4-8. P-values of joint tests on treatment group and study period on weekly dog behaviour. NS = not significant at $\alpha = 0.05$; MS = marginally significant at $0.05 < \alpha < 0.10$

Behaviour (weekly)	P-value
Barking	**0.078**
Drinking	N/A
Eating	NS
Lateral Recumbency	NS
Locomotion	**0.001**
Lying head-down	N/A
Lying head-up	NS
Scratching	NS
Sitting	NS
Sniffing	**0.003**
Standing	NS

Marginal differences of barking behaviour were detected as indicated by the joint test (P=0.078) and are shown in Table 4-9. Pairwise comparisons of group 1 show that barking behaviour tended to be higher during the control period than during the baseline (P=0.010) and treatment periods (P=0.039). No other significant differences within and between groups and periods were detected. Fixed effects of treatment accounted for 1% of the variance (marginal

R^2=0.010), while the full model, including random effects, accounted for 5.7% of the variance (conditional R^2=0.057).

Table 4-9. Mean barking behaviour proportions (%) with 95% confidence intervals from the GLMM model on the response scale. Within a column, a different superscript indicates significant differences within the group; within a row, P-value indicates differences between the groups for the specific period: NS = not significant at $\alpha = 0.05$; MS = marginally significant at $0.05 < \alpha < 0.10$

Study Period	Group 1 Means (%; treatment then control)	Group 2 Means (%; control then treatment)	P-value
Baseline	10.9^{a} (5.05-21.8)	13.2^{A} (6.61-24.7)	NS
Treatment (1)/Control (2)	15.1^{a} (8.24-26.0)	15.3^{A} (8.41-26.2)	NS
Control (1)/Treatment (2)	22.7^{b} (13.29-36.0)	18.0^{A} (10.08-30.1)	NS

Significant differences of locomotion behaviour between groups or periods as indicated by the joint test (P=0.001) are shown in Table 4-10. Pairwise comparisons of group 1 showed less locomotion during the baseline period than during the control (P<0.001) and treatment periods (P=0.001).

Table 4-10. Mean locomotion behaviour proportions (%) with 95% confidence intervals from the GLMM model on the response scale. Within a column, a different superscript indicates significant differences within the group; within a row, P-value indicates differences between the groups for the specific period: NS = not significant at $\alpha = 0.05$; MS = marginally significant at $0.05 < \alpha < 0.10$

Study Period	Group 1 Means (%; treatment then control)	Group 2 Means (%; control then treatment)	P-value
Baseline	5.07^{a} (3.58-7.13)	4.67^{A} (3.28-6.60)	NS
Treatment (1)/Control (2)	7.34^{b} (5.42-9.86)	6.37^{B} (4.68-8.61)	NS
Control (1)/Treatment (2)	7.44^{b} (5.51-9.99)	6.75^{B} (4.97-9.11)	NS

Similarly, in group 2 there was also less locomotion during the baseline period than the treatment (P=0.002) and control periods (P=0.011). There were no detectable differences between the two groups during concurrent study periods. Fixed effects of treatment accounted for 0.2% of the variance (marginal R^2=0.002), while the full model, including random effects, accounted for 1.1% of the variance (conditional R^2=0.011).

Differences of sniffing behaviour between groups or periods as indicated by the joint test (P=0.003) are shown in Table 4-11. Pairwise comparisons showed that in group 1, there was more sniffing behaviour during the baseline period than the control period (P<0.001) and tended to be more than during the treatment period (P=0.054). There was also more sniffing during treatment period than the control period (P=0.040).

Table 4-11. Mean sniffing behaviour proportions (%) with 95% confidence intervals from the GLMM model on the response scale. Within a column, a different superscript indicates significant differences within the group; within a row, P-value indicates differences between the groups for the specific period: NS = not significant at $\alpha = 0.05$; MS = marginally significant at $0.05 < \alpha < 0.10$

Study Period	Group 1 Means (%; treatment then control)	Group 2 Means (%; control then treatment)	P-value
Baseline	4.55^{a} (3.08-6.68)	4.07^{A} (2.74-5.99)	NS
Treatment (1)/Control (2)	$3.69^{\dagger a}$ (2.53-5.37)	3.52^{AB} (2.41-5.12)	NS
Control (1)/Treatment (2)	3.01^{b} (2.05-4.41)	3.20^{B} (2.18-4.67)	NS

†Marginal difference between group 1 treatment 1 and baseline

Group 2 pairwise comparisons showed more sniffing only during the baseline period than the treatment period (P=0.029). No differences were detected between the treatment groups across concurrent periods. Fixed effects of treatment accounted for 0.1% of the variance (marginal R^2=0.001), while the full model, including random effects, accounted for 1.2% of the variance (conditional R^2=0.012).

4.3.4 Faecal Glucocorticoid Data

A total of 31 faecal samples were collected, freeze-dried, ground, and assayed using faecal cortisol ELISA. One sample tube broke in the centrifuge, leaving a total sample size of 30. The sample sizes for each period are indicated in Table 4-12. Mean FGM concentrations with SEM per period are also shown (see Figure 4-5).

Table 4-12. Total number of dog faecal samples collected from group 1 and group 2 during each period of the study before being assayed using a faecal cortisol ELISA

Group	Period	Total Samples
1	Baseline	4
	Treatment	3
	Control	8
2	Baseline	2
	Treatment	7
	Control	6

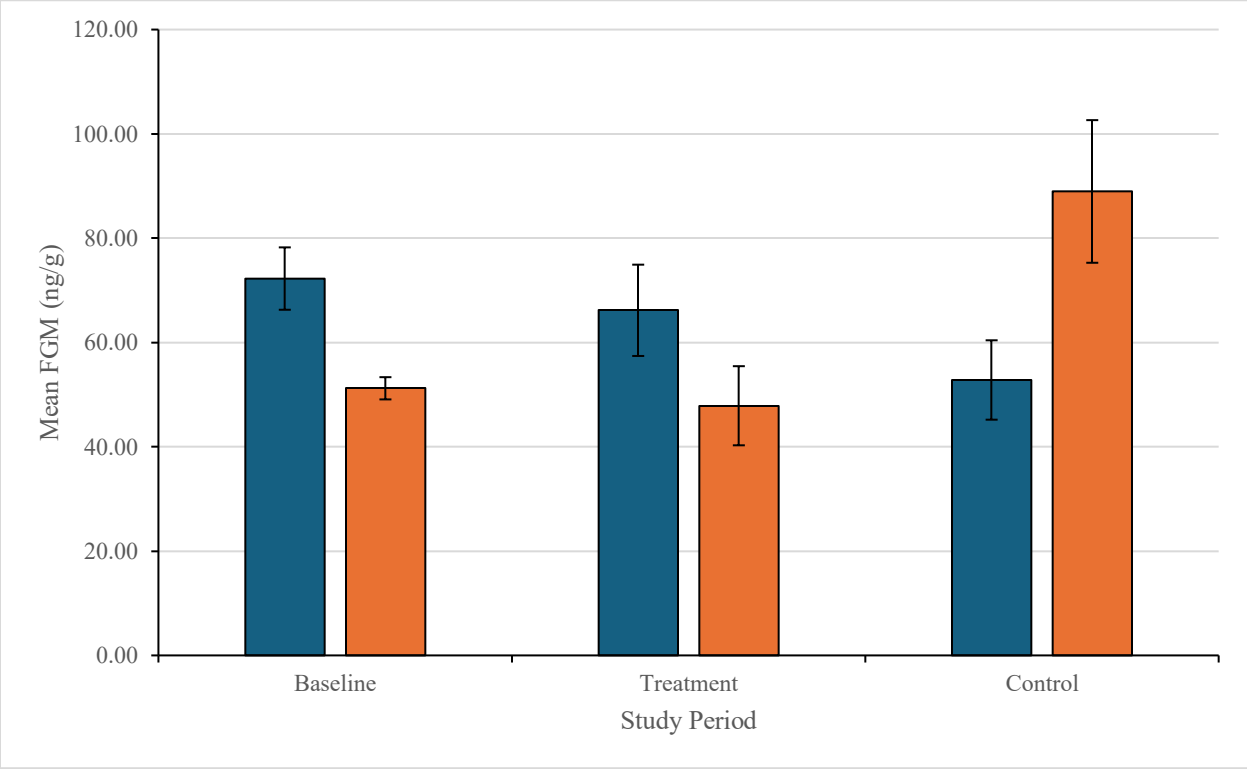


Figure 4-5. Mean observed faecal glucocorticoid metabolite (FGM) concentration (ng/g) with SEM for group 1 (4 dogs; blue bars) and group 2 (4 dogs; orange bars) in the associated study period

Differences of FGM concentrations between treatment group and study period as indicated by joint tests ($P<0.001$) are shown in Table 4-13. Pairwise comparisons of group 1 showed no detectable differences of FGMs between study periods within the group.

Table 4-13. Dog FGM concentration (ng/g) with 95% confidence intervals from the GLMM model on the response scale. Within a column, a different superscript indicates significant differences within the group; within a row, P-value indicates differences between the group for the specific period: NS = not significant at $\alpha = 0.05$; MS = marginally significant at $0.05 < \alpha < 0.10$

Study Period	Group 1 Means (ng/g; treatment then control)	Group 2 Means (ng/g; control then treatment)	P-value
Baseline	76.7^{a} (59.8-93.5)	37.7^{A} (15.3-60.2)	MS
Treatment (1)/Control (2)	62.6^{a} (39.0-86.3)	74.1^{B} (53.9-94.2)	NS
Control (1)/Treatment (2)	58.6^{a} (41.3-75.9)	43.8^{A} (24.8-62.7)	NS

Pairwise comparisons of group 2 showed higher FGM concentration during the control period than then baseline (P=0.005) and treatment period (P<0.001). Comparisons between group 1 and 2 indicated that group 1 tended to have higher FGM concentration during the baseline period (P=0.081). Fixed effects of treatment accounted for 35.8% of the variance (marginal R^2=0.358), while the full model, including random effects, accounted for 85.3% of the variance (conditional R^2=0.853).

4.4 Discussion

This study aimed to examine changes that could be correlated to added human-animal interaction over a 5-week period in November and December 2025. This period corresponds to late-spring and start of summer in the study location (Centre for Canine Nutrition, Palmerston North, New Zealand). The findings showed significant differences in ODBA, locomotion, and sniffing, and found marginal differences in barking behaviour. These findings suggest that the differences in activity and behaviour between groups when comparing to their own baseline could have been a result of increased human-animal interaction. Results were not presented as a classic crossover design as the researcher conducted analysis of variables as a combined variable that included the study group, study period, and the order of treatment to analyse behavioural

responses during each period of the study, which did not examine interactions between variables. The analysis aimed to evaluate if there were overall effects of added human-animal interaction on the behaviours, and not on the consistency of effects between the groups.

Additional human-animal interaction may have increased activity, measured by ODBA, especially in treatment group 1. Group 1 showed a significant increase in activity in the treatment period compared to the other periods of the study, whereas group 2 also showed a significant increase in activity in the same weeks albeit during the control period for them, so it is not possible to determine if the added interaction was the sole cause. However, the researcher going into the paddocks to collect specific dogs for interaction caused the activity levels of all other dogs to rise as they showed increased activity when noticing people. Thus, it can be concluded that activity could potentially increase with added human-animal interaction, even if indirectly. A longer-term study without a crossover design should be conducted to further distinguish the effects of added interaction, and if possible, to see if just human presence from a distance can affect activity.

The observed weekly time budget proportions were similar to those reported in a previous study of the same colony dogs (Redmond et al., 2025), indicating that the accelerometery and data processing models determined a similar breakdown of behaviours as previous studies. There were no differences of means across control and treatment for active, inactive, and maintenance behavioural categories, indicating that on a broader scale, additional human-animal interaction did not result in any differences due to treatment.

Barking behaviour had a trend of increased expression over time specifically for group 1. This may be explained by the fact that dogs are descendants of pack hunters, and much more accustomed to communicating, and barking is one of the main methods of dog communication as

it works even without vision of the target (Serpell, 2017). Since the dogs may have started to associate added interaction with a positive experience where treats were given to elicit certain behaviours, a possible explanation is that the dogs communicated with the researcher more as the study went on as an attempt to obtain more treats. The lack of a trend in group 2 makes sense as well, as their treatment period occurred later in the study (weeks 4/5) compared to in group 1 (weeks 2/3), so there was not yet an association between treats and the researcher. Barking behaviour could also potentially be linked to the sex of the dog, as the female dogs (both in group 1) was observed to have a higher tendency to bark for treats when compared to the males, even on sight of the researcher after their treatment period (weeks 2/3). Further studies should be conducted while factoring in the sex of the dogs.

Locomotion significantly increased throughout the study. In both groups, locomotion was significantly higher after the baseline periods, but with no significant differences between control and treatment periods, which indicates that the increases in locomotion may just be due to the presence of the researcher instead of specifically due to the added interaction. This suggests that even just the sight of the researcher may potentially lead to higher locomotion behaviours, which is supported by data from both groups. A potential way to test this in future studies is to measure behavioural proportions with presence of humans as the independent variable to be tested.

Sniffing behaviour decreased throughout the study in both groups. For group 1, the sniffing behaviour decreased most dramatically during the treatment period, but the sniffing did also decrease simultaneously in the group 2 control period, albeit non-significantly. In group 2, there was also a decrease in sniffing during the treatment period compared to the baseline, indicating that added interaction did decrease sniffing behaviour. This is interesting as sniffing behaviour is highly associated with dogs, and humans make use of it for various tasks like

following a trail (Lea and Osthaus, 2018) or finding contraband (Bräuer and Belger, 2018). A possible explanation is that the predictability of the treat administration during the study decreased natural exploratory sniffing behaviours. This could also be explored in future work, which could investigate the effects of additional food/treats on expressed behaviours.

The observed dog FGM levels in this study were comparable to ranges found in salivary cortisol collection (Bennett and Hayssen, 2010), seemingly slightly higher than blood plasma of dogs in an animal shelter (Hennessy et al., 1997), and higher than cortisol found in hair (Bennett and Hayssen, 2010). Although the concentrations are different to other methods as FGMs are metabolites of cortisol, FGM analysis is still useful for comparing concentrations between weeks and is non-invasive as no contact with the dogs was required.

Added human-animal interaction appeared to have reduced the FGM levels during the duration of this study, especially in group 2 (control period then treatment period; see Table 4-13). This suggests that human-animal interaction could decrease the stress levels of dogs since cortisol levels are reported as a key indicator of stress (Ahmed et al., 2023). During the treatment period of group 1, there was a significantly higher level of cortisol in the simultaneous control period of group 2. This indicates that there may have been external influences that significantly increased FGM levels, such as the presence of the researcher. Moreover, the R^2 levels indicated that around a third of the variance was accounted for by the fixed effects of the treatment, meaning that there was a good chance that the interaction decreased the faecal cortisol levels. However, the dataset was small, and there were only two datapoints in the group 2 baseline period, so the results should be viewed with caution, and further study should be conducted with faecal cortisol sampling, with emphasis on obtaining enough samples in colony dogs to obtain a more representative dataset to work with.

4.5 Conclusion

This study aimed to examine changes in dog activity and behaviour when human-animal interaction in the form of training sessions was added to their normal management routine. This was done by utilising previously validated machine learning models in conjunction with collar-mounted ActiGraph accelerometer devices to quantify and analyse activity and behaviour.

Although changes were detected in ODBA, barking, locomotion, and sniffing behaviour, it is not known how long the effects persisted for, and if these differences are able to be replicated as this is one of the first studies to examine interaction from the point of view of the dog and there were confounding effects. More research should be conducted to determine any longer-term effects of human-animal interactions on the behaviour of dogs, considering more variables such as the presence of humans or predictable treating patterns to better gauge the cause and effects. The results suggest that the interactions possibly increased the welfare of the dogs by lowering faecal cortisol levels, and it is now known that faecal cortisol analysis by faecal cortisol ELISA is a viable method for comparing non-acute cortisol levels adequately across a period.

Chapter 5. General Discussion

This study aimed to examine effects of added human-animal interaction on the behaviour of cats and dogs, across a 4-week and 5-week period, respectively, between October-December 2025. An additional aim was to establish a faecal glucocorticoid metabolite ELISA technique and utilise it to investigate whether cortisol levels were affected as well. The findings of both chapters showed significant increases in ODBA and decreases in faecal cortisol levels in response to the interaction.

The behavioural time budgets differed between the two species. The only difference was that cats sat more than they stood while dogs stood more than they sat, which may be reflective of physical function. There were no differences of means across treatment groups for active, inactive, and maintenance behavioural categories in both cats and dogs, indicating that in observed behaviour on a broader scale, additional human-animal interaction did not result in differences between treatment groups.

In terms of specific behaviours, locomotive behaviour increased throughout the trial in both cats and dogs. This may be explained by the fact that increased interaction with the researcher involved more overall movement (moving from pen to pen, from room to room, for the additional interaction time, which involved a running wheel for cats). In the cat study, only the treatment group had significantly increased locomotive behaviour. while in the dog study, both groups had increases in locomotion compared to baseline, but no difference between control and treatment periods, which indicated that the increase may have been due to the presence of the researcher.

Species specific behavioural changes included a significant decrease of scratching behaviour in the feline study, a trend of increase of barking behaviour, and a decrease of sniffing behaviour in the canine study. An important observation was that the behaviours with significant

changes due to the treatment were behaviours closely associated with the identity of each species. For example, grooming is a behaviour that has been a topic of interest in studies involving cats (Watanabe et al., 2005), with scratching behaviour defined as being a part of maintenance behaviours in both cats and dogs (see Table 2-3) and involved in grooming (Eckstein and Hart, 2000). In contrast, barking and sniffing are both behaviours highly associated with dogs as barking is a main method of communication in dogs (Serpell, 2017), and sniffing has been extensively studied in dogs (Lisberg and Snowdon, 2009; Serpell, 2017), especially because of its ability to be trained for scent discrimination (Bräuer and Belger, 2018; Lea and Osthaus, 2018). A possible explanation for these changes is that human-animal bonding may have been occurring, as cat scratching behaviour, which is associated with grooming behaviour in this context, decreased, which may indicate contentment with the "allogrooming" the cat received from the researcher during the human-animal interaction. Bonding with the dogs may also be occurring, as the dogs begin to associate the researcher with new environments, interactions, treats, and began barking for attention more often. Decreased sniffing behaviour may be due to focus on the researcher but would be a point of future research to further determine if it can be replicated and how long the effect persists for.

Faecal glucocorticoid metabolite levels decreased throughout both cat and dog studies, providing a comparison of the stress the animals endured. Overall, there were much higher amounts of FGM in cats, which were consistently in the hundred-thousand range, compared with the tens to hundreds seen in dogs (see Table 3-12, Table 4-13). This was expected as FGM values for cats were generally documented as higher than in dogs (Wojtaś et al., 2022). The effects are even more drastic in faecal cortisol sampling due to physiological differences (Schatz and Palme, 2001), where cats excreted 82%±4% of cortisol in faeces while dogs only excreted 23%±4%.

Regarding how the FGM concentrations changed in response to additional human-animal interaction, both species reacted similarly with decreased levels of FGMs during the treatment periods compared to control periods in some groups. These findings suggest that increased human interactions with colony cats and dogs have the potential to increase their welfare, a finding which may even extend into the household cats and dogs. The faecal sample size was small in both studies, so care should be taken when interpreting the results. However, the R^2 value of both indicate that the model adequately accounts for the variance with values above 80%. The treatment explained a much higher proportion of variation in dogs, indicating that human-animal interaction could decrease FGM concentrations and consequently stress levels more in dogs compared to cats, as it seems that random factors accounted for more variation in cats. Future work should be carried out to see how FGM concentrations of colony cats change in response to external factors (weather, seasons, colony/kennel/house environment), and in response to increased human-animal interaction, with increased animal numbers and a more refined method of securing more samples for analysis.

Regarding overall limitations of the methodology as a whole, there were some flaws identified post-hoc. During analysis, the treatment group, study period, and sequence of treatment (in the dog chapter) were combined into a single variable for analysis as the focus was to identify any changes in expressed behaviours and the direction due to the defined study conditions (study period, treatment/no treatment; control/treatment group). This pre-defined variable used for the GLMM analysis then resulted in an inability to separately analyse variables and test for interactions between the variables. In further studies, the variables should be separated to test effects of interactions now that it is known that some of the behaviours were indeed be affected by the added human-animal interaction, and results of a crossover trial can be

organised in a more fitting manner. For the FGM parts of the study, the analysis was conducted similarly to how the behaviours were analysed with a GLMM and a combined analysis variable, so the same limitations can be applied. Further analysis can be conducted in the future to further test interactions of variables on the FGM concentration.

Chapter 6. Conclusion

This study aimed to examine changes in cat and dog activity and behaviour when human-animal interaction in the form of playtime and training sessions was added to their normal management routine. This was done by utilising previously validated machine learning models in conjunction with collar-mounted ActiGraph accelerometer devices to quantify and analyse activity and behaviour. In addition, stress levels were assessed using FGM concentrations at the same time.

Although changes were detected in ODBA, locomotion, scratching, barking, and sniffing, it is not known how long the effects will persist for, and if these differences are able to be replicated as this is one of the first studies to examine interaction from the point of the view of the cat or dog and there were confounding variables and methodological limitations More research should be conducted to determine longer-term effects of human-animal interactions on the behaviour and welfare of cats and dogs, since we have a duty to see how our pets are affected. Interactions will likely increase welfare of cats and especially dogs by lowering of FGM levels, and faecal cortisol analysis using a faecal cortisol ELISA is a viable method for adequate comparison of non-acute cortisol levels in conjunction with a GLMM model.

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