UNIVERSITY OF TURKU

The Relation of Age, Breed and Environment on Canine Inattention and Impulsivity

Unravelling ADHD-like Behaviour in Three Dog Breed Groups

Biology/Department of Biology

Master's thesis

Author(s):
Miro Kankare

13.11.2025

Turku

Master's thesis

Subject: Biology
Author(s): Miro Kankare
Title: The Relation of Age, Breed and Environment on Canine Inattention and Impulsivity
Supervisors: Virpi Lummaa, Milla Salonen
Number of pages: 75 pages
Date: 13.11.2025

ADHD (*attention deficit hyperactivity disorder*) is a complex and sometimes controversial diagnosis. Research on its causes and impacts is challenging due to its multifactorial origins and variability in symptom presentation, but dog (*Canis familiaris*) may serve as beneficial model species due to their behavioural, neurochemical, and evolutionary similarities to humans. This study assessed differences in inattention and impulsivity among three dog breed groups (companion, herding, primitive dogs) and modelled the relationship of age, breed, sex, environment, and activity in the behaviour of 997 dogs. Data was collected via a questionnaire-based survey by Salonen et al. (2021) and was analysed using t-tests and generalized linear models. Results indicated that 1) the primitive breed group had lower scores in inattention than companion and herding groups; 2) age significantly impacted inattention and impulsivity, with older dogs displaying lower levels of both behaviours; 3) living environment influenced behaviour, especially in herding breeds, where impulsiveness was related to residence type (detached vs. terraced houses); and 4) dogs in detached houses were rated as less inattentive and impulsive than those in terraced houses. Analyses confirmed a negative relationship between age and both inattention and hyperactivity scores. These findings underscore the importance of considering biological and environmental factors when assessing ADHD-like traits in dogs. Further research should include additional breeds, environments, lifestyles, and conditions. This study highlights the potential of dogs as model species for ADHD research, offering insights into cognitive and behavioural adaptations relevant to both evolutionary biology and practical applications for human and animal well-being.

Key words: dog behaviour, ADHD, dog breeds, behavioural ecology, inattention, impulsivity, living environment, evolutionary psychology

Pro gradu -tutkielma

Pääaine: Biologia
Tekijä(t): Miro Kankare
Otsikko: The Relation of Age, Breed and Environment on Canine Inattention and Impulsivity
Ohjaaja(t): Milla Salonen, Virpi Lummaa
Sivumäärä: 49 sivua + liitteet 20 sivua
Päivämäärä: 13.11.2025

ADHD (*attention deficit hyperactivity disorder*) on monimutkainen ja joskus kiistanalainen diagnoosi. Tutkimus sen syistä ja vaikutuksista on haastavaa sen monitekijäisten syiden ja oireiden esiintymisen vaihtelun vuoksi, mutta koira (*Canis familiaris*) voi toimia hyödyllisenä mallilajina, kun halutaan ymmärtää ADHD:n syitä. Tämä johtuu koirien ja ihmisten käytöksellisistä, neurokemiallisista ja evolutiivisista yhtäläisyyksistä. Tutkimuksessa arvioitiin kolmen koiraroturyhmän (seura-, paimen- ja alkukantaiset koirat) tarkkaamattomuus- ja impulsiivisuuseroja ja mallinnettiin iän, rodun, sukupuolen, ympäristön ja aktiivisuuden suhdetta näiden käyttäytymiseen 997:n koiran muodostamasta aineistosta. Tiedot keräsivät kyselytutkimuksella Salonen ym. vuonna 2021 ja ne analysoitiin t-testeillä ja yleistetyillä lineaarisilla malleilla. Tulokset osoittavat, että 1) alkukantaisella roturyhmällä oli matalammat pisteet tarkkaamattomuudessa kuin seura- ja paimenkoiraryhmillä; 2) ikä vaikutti merkittävästi tarkkaamattomuuteen ja impulsiivisuuteen, kun vanhemmilla koirilla oli näissä käyttäytymisissä matalammat tasot; 3) elinympäristö vaikutti käyttäytymiseen erityisesti paimenroduilla, joissa impulsiivisuus liittyi asuinpaikkatyyppiin (omakotitalot vs. rivitalot); ja 4) omakotitalojen koirat arvioitiin keskittymiskykyisimmiksi ja vähemmän impulsiivisiksi kuin rivitaloissa asuvat. Analyysit vahvistivat negatiivisen suhteen iän ja sekä tarkkaamattomuuden että hyperaktiivisuuden välillä. Nämä havainnot korostavat, että biologiset ja ympäristötekijät ovat tärkeä huomioida, kun arvioitaan koirien ADHD:n kaltaisia piirteitä. Jatkotutkimuksen tulisi sisältää lisää erilaisia koirarotuja, ympäristöjä, elämäntapoja ja olosuhteita. Tämä tutkimus korostaa, että koiria on mahdollisuus käyttää mallilajeina ADHD-tutkimuksessa. Ne auttavat ymmärtämään kognitiivisia ja käyttäytymiseen liittyviä adaptaatioita, jotka ovat merkityksellisiä sekä evoluutiobiologian että ihmisten ja eläinten hyvinvoinnin käytännön sovellusten kannalta.

Avainsanat: koiran käyttäytyminen, ADHD, koirarodut, käyttäytymisekologia, tarkkaamattomuus, impulsiivisuus, elinympäristö, evoluutiopsykologia

Contents

1 Introduction

1.1 Background

ADHD (*attention-deficit/hyperactivity disorder*) is one of the most common neurodevelopmental disorders for children worldwide (Centers for Disease Control and Prevention 2025; Hale et al. 2013). Neuro-based disorders are not only common, but ADHD is also one of the few mental disorders that can be treated with medicine. (National Institutes of Health 2024) However, a wide range of negative functional impacts on attentiveness, impulse control, emotional dysregulation and relationship difficulties from therapeutic activities in ADHD has been documented (American Psychiatric Association 2013; Shaw et al. 2014; Soler-Gutiérrez et al. 2023). Impacts on patients from common activities such as education and working life (Biederman & Faraone 2006) include reduced activity, consistency, and breadth of sensory defensiveness (López-Hernández et al. 2024), and, for diagnosis, there must be an increase in the diversity and cover of more tolerant traits including hyperactivity and inattentiveness (American Psychiatric Association 2013).

Genetics are fundamental to ADHD. ADHD is highly heritable (70-80 %) both in childhood (Nikolas & Burt 2010) and in adults (Brikell, Kuja-Halkola & Larsson 2015). Emotional dysregulation (Shaw et al. 2014) and neural and genetic mechanisms (Gallo & Posner, 2016) cause excessive amount of inattention, hyperactivity, and impulsivity, characteristics of ADHD (American Psychiatric Publishing, 2013). The general features of molecular genetics of ADHD are not so well known. ADHD is a complex trait and so in order for genes to be discovered, a massively large dataset is required, because the importance of each gene is very small, and a huge number of genes can influence this trait. Genetic studies have indeed shown that the effect of an individual gene is very small (Faraone & Larsson 2019).

The prevalence of ADHD has also been explained in recent years from the evolutionary psychology point of view, which considers that a key aspect is to compare an individual's environment of evolutionary adaptedness (EEA) to current habitat. Recently, there has been renewed interest in several behavioural disorders including ADHD (Sayal et al. 2018), and their evolutionary explanations (Swanepoel et al. 2017). In evolutionary biology, evolutionary mismatch means that rapid change in environment may lead to maladaptive trait, although the trait was

advantageous in the past. Mismatch has been studied and suggested as a cause of mental and neurodevelopmental disorders. The prevalence of mental disorders has increased with industrialization in Western countries and mismatch is a possible explanation for this finding (Chaudhary & Salali 2022). Environment of evolutionary mismatch may have caused mental disorders to become more frequent (Chaudhary & Salali 2022). If current environment differs from environment of evolutionary adaptedness, it may cause once adaptive traits to be maladaptive in the new environment (Chaudhary & Salali 2022). Knowledge of evolutionary thinking may have great importance for management of symptoms. The relationship between genes, environment, and their interactions and proportions for behavior is a classic and complicated problem in evolutionary biology.

Environment is a major contributor to mental health. ADHD is caused by many accumulating environmental and genetic factors and therefore, non-genetic factors probably contribute to the emergence of attention deficit problems (Thapar et al. 2013). There is no evidence of causality, although environmental toxins (like exhaust fumes), low greenness and other features of urban environment (Yuchi et al. 2022), as well as low level of physical exercise (especially in children; Zang 2019) and diets (Pelsser et al. 2017), such as high sugar intake (Del-Ponte et al. 2019; Kozyra et al. 2020;), artificial food colors (Stevens et al. 2011) and other ultra-processed foods (Kozyra et al. 2020), and nutrient deficiencies (Sinn 2008; Zhang et al. 2020) have been suspected to lead to attention deficit/hyperactivity disorder. However, alternative explanations also exist, like worse socioeconomic status of urban dwellers (for example, through inadequate housing conditions; Braubach & Savelsberg 2009) and higher likelihood of moving to a city in those prone to mental health problems.

Recent studies have reported a higher prevalence of ADHD symptoms in urban environments (Ahmeti et al. 2025; Siddique et al. 2011; Mattos et al. 2024), and among individuals engaged in urbanized lifestyles (LeBlanc 2021). One explanatory framework that has gained attention in this context is the evolutionary mismatch hypothesis. This hypothesis posits that certain cognitive and behavioural traits, which may have been adaptive in ancestral environments, can become maladaptive in modern settings that differ significantly from those in which humans evolved. Urban environments, characterized by high population density, sensory overstimulation, and reduced opportunities for physical activity, may exacerbate traits associated with ADHD.

However, the evolutionary novelty of urban living does not inherently imply a causal relationship with increased mental health disorders. While some empirical studies have identified correlations between urban stressors—such as socioeconomic deprivation, environmental degradation, and neighborhood (e.g., visible signs of neglect like graffiti and broken windows)—and elevated rates of anxiety and depression (Wu et al., 2017), eventually, conclusions of causal relationships cannot be inferred, and generalization-based results and theories in evolutionary psychology need to be noted carefully.

Faraone et al. (2021) found a probable relationship between many combined effects of genetic and environmental risks and ADHD. These environmental risks likely have most influence in the post-fetal period. In the field of evolutive psychiatry, mental disorders like schizophrenia and autism spectrum disorders have been studied more, but less attention has been paid to ADHD. As a result, no comprehensive evolutionary theory appears to exist for ADHD.

Rodent models have been extensively developed for the investigation of mental disorders due to the fundamental similarities in physiological and neurological functions between rodents and humans. Moreover, certain experimental procedures, such as the creation of gene knock-out individuals, are ethically and practically unfeasible in human subjects. In this context, a "knock-out" refers to a genetic engineering technique commonly employed in animal research, particularly in mice—where a specific gene is deliberately inactivated to study its biological function. Disorders that do not have animal models are more poorly understood than disorders that have (Russel et al. 2005). A standard procedure for assessing ADHD-related behaviors has been the use of rats and mice (Boix et al. 1998; Vas et al. 2007).A much-debated question is whether animal models are sufficiently appropriate for studying ADHD (Majdak et al. 2016), given that ADHD remain under-recognized or poorly understood in humans (Sayal et al. 2018), which complicates the development of accurate and representative animal models. Weaknesses of rodent models are that they are neither comprehensive (Regan et al. 2022) nor appropriate (Majdak et al. 2016), as they often fail to replicate the full complexity of human physiology and disease and may exhibit species-specific responses that limit their translational relevance to human conditions. This classical view of using rodents as animal models is challenged by recent studies showing that dogs could provide a potential animal model (Miklosi et al. 2004; Vas et al. 2007; Sulkama et al. 2021), especially since dogs and humans have shared same evolutionary environment. Of the diseases that occur in humans, a large number also occur in dogs (Hytönen

& Lohi 2016). In humans and dogs, social behavior, current habitat, genome and physiology are similar.

Quantifying the impact of ADHD by any measure requires information on attentiveness, impulsiveness and the behavior of the individual. For (unintended) ADHD traits on dogs, including that by owners in different living environments, all these factors can be measured, and environmental and lifestyle patterns can be estimated. Comparison of different dog breeds on different types of lifestyles and for different behaviors can indicate the role of EEA in causing ADHD-like behavior (including that especially on primitive dog breeds). While there are many recent examples of modelling and experimental studies of ADHD (for example: Casey et al. 2007; reviewing animal models: Kim et al. 2024) from evolutionary perspective (Le Cunff 2024; Williams & Taylor 2006) and for a limited selection of dog models (Vas et al. 2007; Puurunen et al. 2016; Sulkama et al. 2021; González-Martínez et al. 2023), studies of ADHD on dogs are rare.

It is still not known whether dog models can accurately capture the characteristics of ADHD, as dogs naturally exhibit varying levels of inattention and hyperactivity occur in dogs (Salonen et al. 2020), or how environmental factors contribute to these traits. Even less is known about environmental mismatches, often implicated in the disorder. However, it is not clear whether all dog breeds work equally well as animal models for studying mental and neurodevelopmental disorders (Zapata et al. 2022; Kaur et al. 2023). Dogs have been bred for various purposes, and they have been used in different tasks, and different-looking dogs have been differentiated into closed breed populations, which has resulted in genetic and behaviour differences between dog breeds (MacLean et al. 2019; Dutrow et al. 2022). Respectively, some breeds remain more primitive, while others have been more selectively bred (Konno et al. 2016; Smith et al. 2017). Therefore, these differences need to be analyzed in relation to their suitability as ADHD models, particularly in how they respond to environmental mismatches often implicated in the disorder.

I have organized this thesis in the following way: in section 2, I describe the framework for the survey data, using dogs as animal models and statistical models. In section 3, I present the results. In the last section, I will discuss the results and especially focus on whether they can be applied understanding ADHD on humans. Throughout this thesis, the abbreviation ADHD will

refer to Attention-Deficit/Hyperactivity Disorder, EEA will refer to environment of evolutionary adaptedness and GLM will refer to generalized linear model.

1.2 Research Questions

In this thesis, I investigate the relationship between environment, impulsiveness, and inattention in three distinct dog breed groups, with a focus on evolutionary psychology. The specific objectives of this thesis were to study: 1) do the three breed groups differ in their average levels of inattention and impulsiveness? Herding breed group is predicted to show higher impulsivity and inattention scores than companion breed groups due to their evolutionary adaptation to environments requiring vigilance and responsiveness (Fadel et al. 2016), as well as historical selection for high energy, while companion breeds are expected to exhibit lower impulsivity due to breeding for calm temperament and sociability (Salonen et al. 2020). 2) How do breed group, sex, age, living environment, and activity level relate to impulsivity and inattention scores across the full sample, and 3) are these associations consistent within each breed group? Younger dogs males, and those living in urban environments or receiving less exercise are predicted to show higher impulsivity and inattention scores (about age and exercise on dogs: O'Rourke et al. 2025; about humans living in urban environment: García de Jalón et al. 2021), consistent with findings in both canine and human ADHD research suggesting that overstimulation, reduced physical outlets, and developmental or hormonal factors contribute to these traits (Vas et al. 2007; Rommel et al. 2013; Salonen et al. 2021; Sulkama et al. 2021).

Data for this study were collected by Salonen et al. (2018–2020), through a large-scale survey on dog personality and unwanted behaviour. This data is used to assess behavioural differences among three dog breed groups. The impulsive and inattentive behaviour section of the survey was originally adapted from Vas et al. (2007), and a factor analysis has grouped the items into two traits: impulsivity/hyperactivity and inattention. Factor scores for each dog were calculated.

In this thesis, I use statistical methods to examine the dynamics of inattentive and impulsive behaviour across breed groups, as well as the variables related to these traits. First, I tested whether breed group membership (e.g., companion vs. herding) significantly affects impulsivity and inattention scores. I used GLM to test whether covariates like age and sex contribute to explaining variance in these traits. Then, using response about living environment, I analysed how different housing types were related to inattention or impulsivity, compared specific types in pairs, for example, detached versus terraced house.

This thesis focuses on the evolutionary perspective unlike the previous studies that used the survey by Salonen et al. Focus is on examining the differences between these breed groups, so this study builds on the work of Sulkama et al. 2021. This master's thesis can reveal insights into the evolutionary background of ADHD-like behaviour and its association with environment. It also considers the possibility that such traits may reflect shared evolutionary adaptations between dogs and humans, potentially present in early stages of co-evolution.

2 Material and Methods

2.1 Dogs as Animal Models

Many researchers have utilized dogs to measure behaviour traits. A major advantage of dogs is that humans and dogs have similar genetic and environmental factors that can interconnect with impulsiveness (Wright, Mills & Pollux, 2011) and inattention (Vas et al. 2007). For example, a prospective study approach discovered that ADHD-like behaviour was reduced by ketogenic medium chain triglyceride diet (MCTD) (Packer et al. 2015). A major problem with previous studies examining the association between ADHD-like behaviour and environment is that it is not known whether environmental factors are related to these behavioural characteristics common in all types of dogs or only a characteristic of certain types of dogs.

2.1.1 Breed groups

I used three breed groups that would potentially differ in how the environment relates to these ADHD-like traits. In general, dogs can be divided into breed groups based on, for example, behaviour. Behavioural similarities, the purpose of the breed, and the genetic relatedness formed the basis for the breeds and breed groups, that were originally grouped by Salonen et al. (2021). While the breed data were drawn from the Salonen et al. (2021) dataset, breeds were reclassified into these three groups (table 1). I selected primitive dog breeds representing East Asian and Arctic lineages, including those hypothesized to retain ancestral genetic and morphological traits that bridge a gap between wild progenitors and modern domestic dogs (Freedman et al. 2014; Yang et al. 2017; Smith et al. 2024). Breeds for two other groups were selected based on purposes the dog breed is used for: companion dogs and herding dogs.

Table 1. Breeds listed in three breed groups.

Companion breeds	Primitive breeds	Herding breeds
Bichon Frise	Akita	Australian Kelpie
Bolognese	Alaskan Malamute	Australian Shepherd
Cavalier King Charles Spaniel	American Akita	Border Collie
Chihuahua (longhaired and smooth-haired)	Chow Chow	
Coton de Tulear	Greenland Dog	
Havanese	Hokkaido	

King Charles Spaniel	Kai
Lowchen	Kishu
Maltese	Korea Jindo Dog
Russian Toy Dog (longhaired and smooth-haired)	Samoyed
Russian Tsvetnaya Bolonka	Shar Pei
	Shiba
	Shikoku
	Siberian Husky

There would be many other breeds in the groups in the original dataset, and these choices may play a role in the results. Criteria for selecting the dog breeds to be included within each breed group were to choose specific types of dogs that are as genetically pure as possible and phylogenetically close in an ideal scenario. Therefore, all Asian companion dog breeds have been excluded from companion dogs, because phylogenetically they are close to Asian primitive breeds. Breeds that are as purely herding dogs as possible, i.e., breeds that are still used in herding work, were selected for the herding group. So, there are only three breeds of herding dogs (Border Collie, Kelpie and Australian Shepherd). Only Asian breeds and sled dog breeds were included to the primitive group, because according to Li et al. (2023), primitive sighthounds are completely different and have multiple origins. Companion breed group includes all breeds from the group “bichon type dogs”, as well as some breeds from the “other companion breeds” and the “toy dog” group.

2.2 Survey

Traditionally, behavioural data have been assessed by measuring level of trait. Dog studies have traditionally used, for example, Dog Personality Questionnaire (DPQ). Salonen et al. (2021) utilised questionnaires to analyse various behavioural traits in dogs. Questionnaire-based methods provide a means of systematically collecting and analysing data on various behavioural traits in dogs. A quantitative behavioural approach was adopted to allow a deeper insight into the specific behaviours and characteristics of individual dogs. A major problem with the questionnaire method is that it relies on subjective reporting by dog owners, which may introduce bias. The synthesis of the questionnaire was done according to the procedure of developing adjective-based personality questionnaires for various pets and captive animals. The survey was divided in 9 sections. One of the sections dealt with the background and environment of the dog, and other dealt with the impulsivity/inattention, and these two sections are used in this master's thesis. There were 37 questions in Impulsivity/inattention section. For example, questions about task solving, tail chasing and physical restlessness were included. The survey was translated to Finnish, because the participants in the study were Finnish dog owners. Vas et. al (2007) formulated the section about impulsivity and inattention. (Salonen et al. 2021)

In order to identify factors associated with ADHD-like behavioural traits, the participants were asked to complete detailed questionnaires about their dogs' behaviours (the validated question battery by Vas et al. 2007 consisted of 13 questions). The participants were asked to rate how strongly they agreed with the options ("never", "sometimes", "often", and "very often"). Claims the owners are responding to included questions like "My dog has a difficult time learning, because she/he is careless or other things can easily attract her/his attention." and "My dog cannot wait as she/he has no self-control.". Based on these answers, factor analysis was used to quantify the dog's hyperactivity/impulsivity and inattention inability. For the impulsivity/inattention questions, a Likert scale was used.

The questions about the living environment elicited information on living building and place; environment was defined as urban if living place was in a city centre or in a city or town, but outside the centre (Salonen et al. 2021). The "living_building"' answer consisted of a question "In what kind of building do you live?" and the answer options were apartment other (in an apartment or other), detached house (in (detached) house), or row semi-detached (in a row

house/semi-detached house). For daily exercise, the question was “During a typical day, how many hours/minutes do you walk your dog?” and the answer options were "under 1 hour”, “1-2 hours”, “2-3 hours” or “over 3 hours". Many people engage with dogs e.g., in scent work, agility or obedience training. For hobby frequency, the survey asked the owner how often they engage with the dog at home and outside the home (separately, i.e., two questions about the hobby frequency). The respondent had the following response options to choose from: "never or does not have hobbies”, “infrequent” (a few times a year OR 1 - 3 times a month) or “active” (1 - 2 times a week or more frequent). The most common hobbies in data are dog shows (21% of respondents), agility (19% of respondents) and obedience training (19% of respondents).

To establish whether the questionnaire results were reliable, a test-retest reliability study was conducted. The answers with missing basic information or duplicate answers were excluded. Selected participants received a request to participate in the test-retest reliability study. Two sets of questionnaires were completed by these selected owners, and one questionnaire was completed by other adult family member for inter-rater reliability. For this final questionnaire, questions were asked about how long they have known about the dog, and if the other owner had not discussed their dog’s behaviour with the participant (Salonen et al. 2021).

Reliability was calculated using Cronbach’s alpha; the two ADHD-like behavioural traits had good internal consistency ($\alpha = 0.84$ for inattention and $\alpha = 0.79$ for hyperactivity/impulsivity; Cronbach's alpha should be above 0.7 (Cicchetti 1994)). A Pearson correlation analysis was conducted in order to assess the test-retest reliability ($r=0.79$ for inattention and $r=0.77$ for hyperactivity/impulsivity; the test-retest correlation should preferably be above 0.7 (Litwin 2003)). and intraclass correlation coefficient for inter-rater reliability (ICC (1,1) =0.68, ICC1, k) =0.81 for inattention and ICC (1,1) =0.77, ICC (1, k) =0.87 for hyperactivity/impulsivity). Hypothesis testing was used to estimate the convergent validity of the questionnaire: only 4 of 51 literature-based hypotheses were not true (Salonen et al. 2021). In questionnaire-based studies, there is a potential for bias from the subjective reporting of dog owners, which may affect the accuracy of the collected data.

2.2.1 Derived variables

Compared to the small size of the data, there are a lot of variables included in the original Salonen et al. 2021 data, and many of these variables are strongly correlated. For example, living place, living building and outdoor access are highly correlated. I did the analysis so that I included four interesting variables in the analyses. ADHD has been found to be associated with urbanity and physical activity, so I only included living place, living building, daily exercise and hobby frequency, in addition to covariates: breed, sex and age.

I made the new independent variables that were formed as follows: E (for environment) had four levels: “urban apartment blocks” (living_building was apartment), “urban terraced houses” (living_building was row_semi-detached), “urban detached houses” (living_building was detached house and living_place was “urban”), and “rural detached houses”, where “living_building” was detached house and living_place was “rural”. For Activity variable, there was also four levels: “actively moving and hobbies” (daily_exercise was over_3_hours or 2-3_hours, and hobby_frequency was “active”) and actively moving non-hobbies (daily_exercise was over_3_hours or 2-3_hours and hobby_frequency was “infrequent” or “never_no hobby”). If “daily_exercise” was “1-2_hours” or “under_1_hour”, new level was either less active exercisers (“hobby_frequency” was active) or less non-active exercisers (“hobby_frequency” was infrequent or “never_no_hobby”). I made the new variables using the dplyr package. In this Master's thesis, dependent variables have been created by factor analysis conducted by Salonen et al. (2021), based on 13 questions survey items by Vas et al.

2.2.2 Participants

The total number of respondents was 11,498. Dogs were excluded if there were duplicate answers, missing basic information, dog was deceased more than 3 months ago (206), or dog's birthday was not known (184). The dog's birthday and sex were modified, if they could be verified from other sources (Salonen et al. 2021). Not all sections were completed for every dog. 10,726 dogs were included in Impulsivity/inattention section. (Salonen et al. 2021)

Data was filtered for the thesis as follows: the dog had been answered to both the background and impulsivity/inattention sections and the dog was of the breed as the selected breeds in those breed groups (shown in Table 1), resulting in a total of 997 dogs.

A total of 997 dogs were recorded over the three assessed breed groups, 352 of which were companion dogs (35%), 318 herding breeds (32%), and 327 primitive breeds (33%) (Supplementary tables 13 and 14).

The dogs living at the urban site had most answers of living place on the whole (77% of all answers), dominated by the apartment house living companion breeds (36%), detached house living primitive breed being slightly lower (29%) and the lowest proportion being companion breeds living in the rural detached house (14%). The four housing types were fairly evenly distributed among breed groups (23-27% for each living form) (Appendices, table 14).

The activity had most answers for "less non-active exercisers" (38% for all breeds) and for "active" (25%), being dominated by companion breeds that were "less non-active exercisers" (62%), primitive breed group (42%) and actively moving and engaging herding breed group (37%). Only 5% companion dogs were actively moving and engaging, and only 7% of herding breed dogs were "non-active exercisers" (Appendices, table 14).

Inattentiveness ranged from -1.76 to 4.33 with an average of -0.04 and a standard deviation of 1.02, while hyperactivity/impulsivity ranged from -1.65 to 4.75 with a mean of -0.12 and a standard deviation of 0.94 (means and standard deviations by breed groups: see Table 2). There was a moderate positive correlation (r=0.53) between inattention and impulsivity score (Figure 1).

Figure 1. Plot of impulsivity score as a function of inattention score for dogs that were companion (red), herding (green), or primitive group (blue) (r= 0.53).

Table 2. Mean and SD of inattention and impulsivity score and number of dogs in the breed group.

	Inattention score		Impulsivity score		
Group	mean	SD	mean	SD	n
Companion breed	0.03	0.95	-0.15	0.89	352
Herding breed	-0.50	0.94	-0.03	0.98	318
Primitive breed	0.33	0.99	-0.19	0.96	327

2.3 Data Analysis

I read the data in using the readxl package. I looked at the fit of the model for the data with AICs, residual plots and Q-Q plots. The data was not distributed normally, so I used a generalized linear model with gamma distribution. A p value <0.05 was considered significant.

To determine whether there were significant differences among breed groups in impulsivity and inattention, I performed a two-sample t-test for the impulsivity/inattention scores in three breed groups. All analyses were carried out using RStudio, version 2023.09.0. A Pearson correlation analysis was conducted on both dependent variables to assess the strength of the linear relationship between inattention score and impulsivity score. Parametric tests (t-test) were used to compare the means of impulsivity and inattention between pairs of breed groups. Significance levels were set at the 5% level using the student t-test.

To determine if living in urban living environment or activity relates impulsivity or inattention, linear models were fitted separately for each breed group and both traits, total of six models. The generalized linear models for impulsivity score and inattention score were subjected to analysis of variance (by car package) to determine differences between generalized linear model results (from three breed groups).

I built (generalized linear) models covering all breeds first, which had the breed group as an explanatory variable. Then I built breed-specific models for assessing the impact of breed on the outcome while controlling for other influencing factors. In all these models, I used hyperactivity/impulsivity or inattention as response variables, and sex and age as covariates. I obtained the results of the analyses from R in both graphical and tabulated formats, using ggplot2 and ggResidpanel packages for the plots, and the emmeans package for estimated marginal means.

Artificial intelligence (AI) was utilized during the preparation of this thesis to support language refinement and improve clarity in academic writing. Specifically, Microsoft Copilot (GPT-4 architecture, 2025 versions) was employed to assist with tasks such as paraphrasing, grammar correction, and enhancing the formal tone of scientific text. The AI was not used to generate original research content, interpret data, or draw conclusions.

3 Results

In this thesis, I assessed: (1) the difference in inattention and impulsivity averages of three breed groups, (2) the relation of breed, sex, age, living environment and activity on inattention and impulsivity score in the combined sample, and (3) the impacts of sex, age, living environment and activity on inattention and impulsivity score separately within each three-dog breed group.

3.1 Breed differences

3.1.1 Breed differences in inattention

The first set of question aimed to compare the average inattention scores of three groups of dog breeds, so t-tests have been performed between all pairs of groups (companion vs herding, herding vs primitive, companion vs primitive). Table 3 shows an overview of t-test for inattention score.

Table 3. Statistics of the t-test for inattention score.

	t	DF	p-value
Companion breed x herding breed	7.2	663	**0.000**
Companion breed x primitive breed	-4.0	669	**0.000**
Herding breed x primitive breed	-11	643	**0.000**

As shown in in Figure 2, the primitive breed group owners reported significantly higher inattention than other two breed groups.

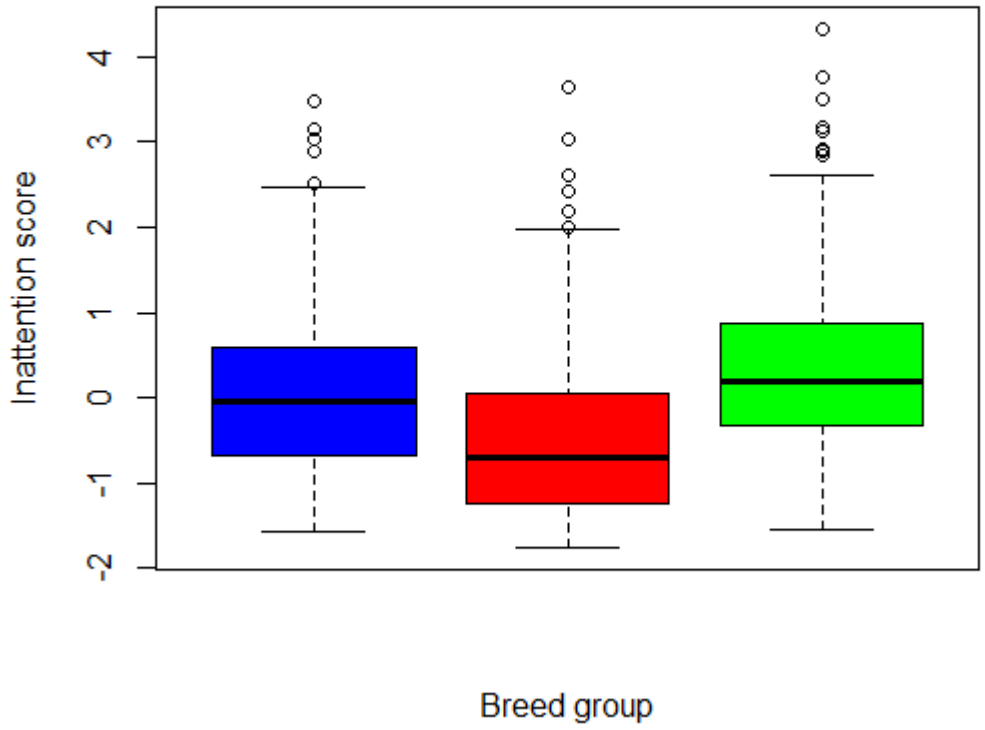

Figure 2. Box plot of inattention score for three breed groups of companion breed (blue), herding (red), and primitive breed (green).

The mean inattention score was 0.33 for the primitive breed group, 0.03 for the companion breed group and -0.50 for the herding breed group. The inattention score of primitive breed group was significantly higher than the inattention score of companion breeds and herding breeds (Table 3). Similarly, the inattention score of the companion breed group was significantly higher than the inattention score of the herding breed group (Table 3).

3.1.2 Breed differences in hyperactivity/impulsivity

To compare the difference between three breed groups for mean impulsivity score, t-tests were performed between all pairs of groups (companion vs herding, herding vs primitive, companion vs primitive). Figure 3 presents the data on impulsivity score.

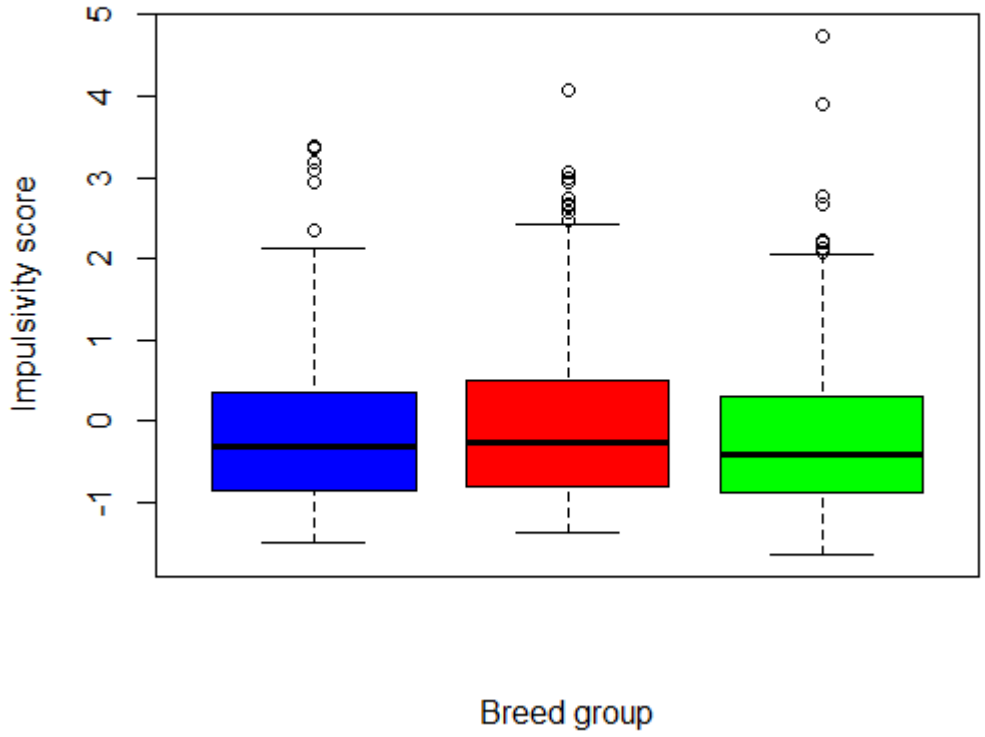

Figure 3. Box plot of impulsivity score for three breed groups of companion breed (blue), herding (red), and primitive breed (green).

As can be seen from the table 4 below and figure 3, the herding group owners reported slightly more impulsivity than other two breed groups. The mean hyperactivity/impulsivity score varied between breed groups: the mean impulsivity score was -0.15 for the companion breed group, -0.03 for the herding breed group and -0.19 for the primitive breed group. The primitive breed group had significantly lower mean score in hyperactivity/impulsivity than herding breed group. No statistically significant difference was observed between companion breed and herding breed, or between companion breed and primitive breed. The results of the t-test for impulsivity are set out in Table 4.

Table 4. Statistics of the t-test for impulsivity score.

	t	DF	p-value
Companion breed x herding breed	-1.7	643	0.097
Companion breed x primitive breed	0.5	662	0.620
Herding breed x primitive breed	-10.8	643	**0.042**

Closer inspection of the table shows less significant p-values. No difference greater than p=0.042 was observed. Only trace amounts of impulsivity score over 0 were detected in breed groups.

3.2 The effects of breed, living environment, and lifestyle to the level of inattention and impulsivity score

3.2.1 Inattention

A generalized linear model was used to estimate relationships between the inattention score and breed group, living environments, and lifestyle. Tables 5 and 6 and figure 4 provide the summary statistics for inattention score.

Table 5. Results of a generalized linear model of the effect of breed, sex, age, environment, and activity. Reported are for each explanatory variables F test statistic with associated degrees of freedom and P value.

Coefficients	DF	test	P
Breed group	2	43.5	**2.20E-16**
Sex	1	2.7	0.103
Age	1	11.2	**0.001**
E	3	2.6	0.052
Activity	3	1.7	0.175

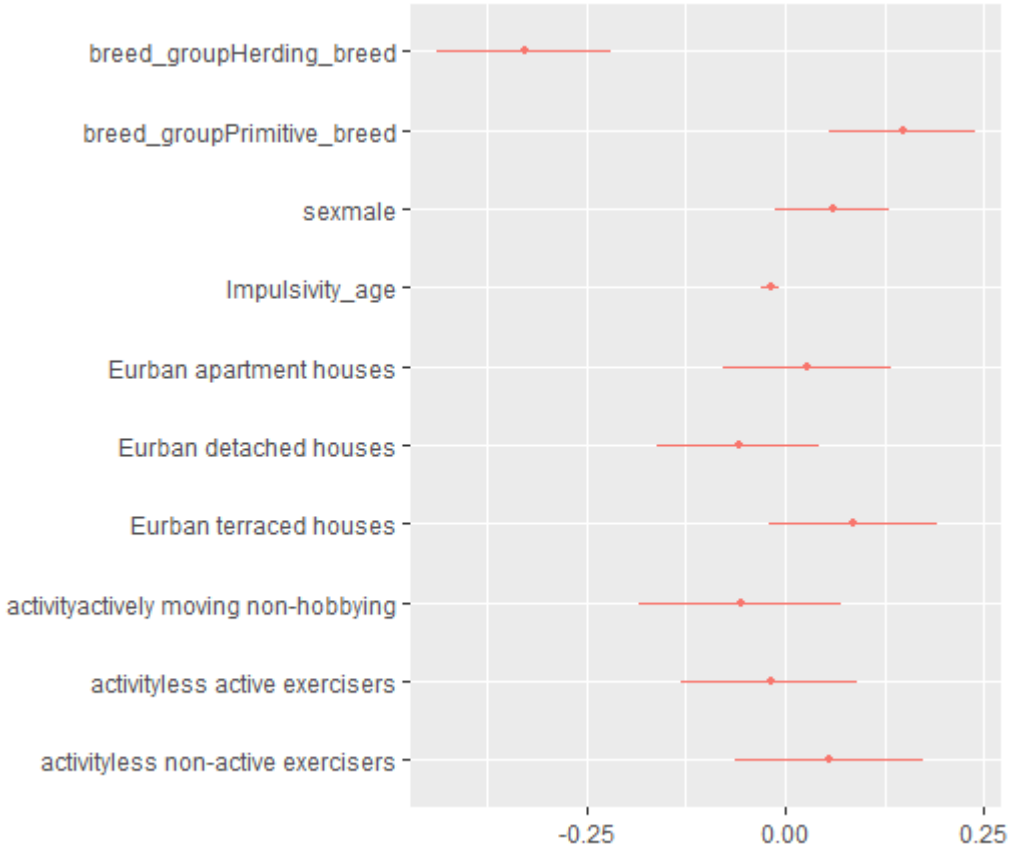

Figure 4. Coefficient plot of estimates (X-axis) and confidence interval of estimated marginal averages for each level of the variable: breed groups, sex, age, environments, and activity to inattention score.

Table 6. Results of paired comparisons of some interesting variables. SE stands for standard error and DF stands for degree of freedom. All results in additional materials.

contrast	estimate	SE	DF	t ratio	p value
Companion breed - Herding breed	0.33	0.055	986	5.9	**<.0001**
Herding breed - Primitive breed	-0.48	0.051	986	-9.3	**<.0001**
rural detached houses - urban apartment houses	-0.03	0.054	986	-0.5	0.957
detached - apartment	-0.06	0.046	986	-1.2	0.215
detached - terraced	1.08	0.047	986	22.9	**<.0001**
apartment - terraced	-0.06	0.052	986	-1.1	0.275
moves a lot - moves a little	-0.05	0.039	986	-1.2	0.232

Breed group ($F_{2,327}$=43.5; P=< 2.2e-16) and age ($F_{1,327}$=9.1; P=0.001) were significantly associated with inattention score. The mean inattentiveness for one-year-old dogs was 6.33 (95% CI: 5.73–7.03), while the mean inattentiveness for 10-year-old dogs was 4.77 (95% CI: 4.32–5.30). Age significantly affects inattention scores, suggesting that the score of inattention varies with age. Results in Table 6 indicated significant differences in inattention scores among the breed groups, with primitive breed group generally having higher scores compared to both companion breed group and herding breed group. No significant relationships were found between activity and inattention score; there was no evidence that activity has an influence on inattention. Statistically significant difference was observed between dogs living in detached house and urban terraced houses. On average, dogs living in terraced houses were more inattentive than those living in detached houses.

3.2.2 Hyperactivity

I studied how breed group, sex, age, living environment and activity reported by the informants are related to impulsivity score using a generalized linear model. Figure 5 and tables 7 and 8 provided the breakdown of breed groups, sex, age, living environments, and lifestyle to impulsivity score.

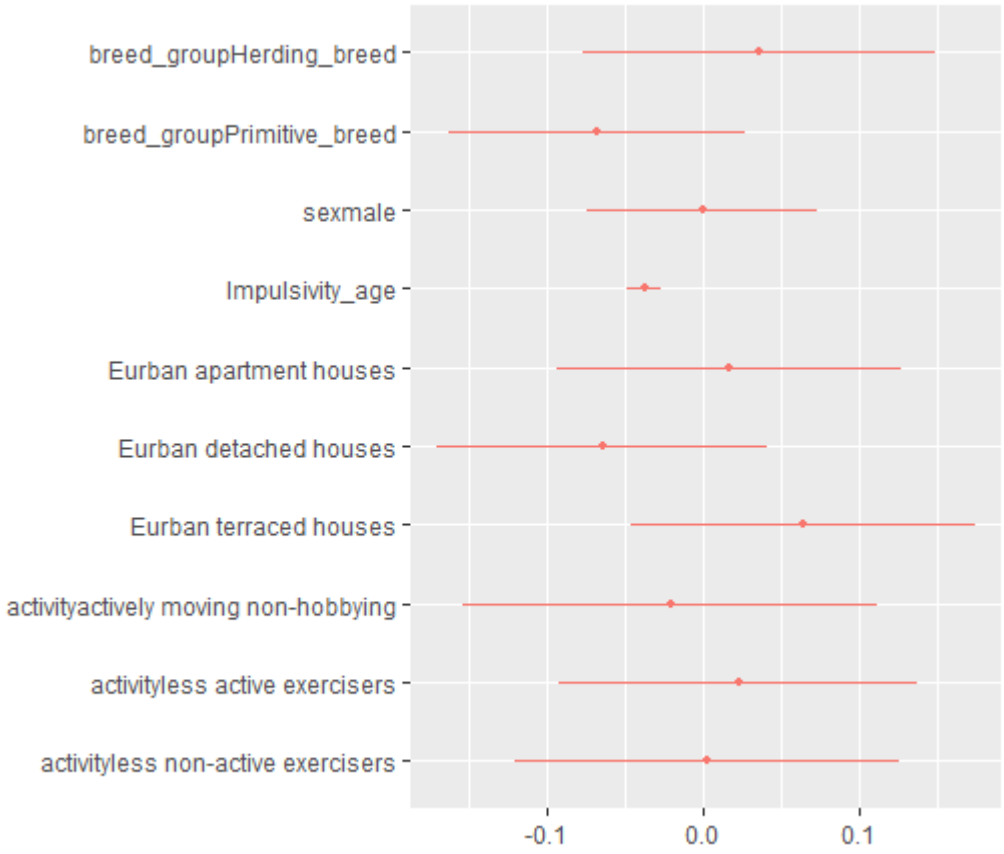

Figure 5. Coefficient plot of estimates (X-axis) and confidence intervals of estimated marginal averages for each level of the variable breed groups, sex, age, environments, and activity to impulsivity score in all breeds groups.

Table 7. Results of a generalized linear model of the effect of breed, sex, age, environment, and activity. Reported are for each explanatory variable its F test with associated degrees of freedom and P value.

Coefficient	DF	test	P
Breed group	2	2.2	0.109
Sex	1	0.0	0.986
Age	1	43.7	**6.23E-11**
E	3	1.9	0.121
Activity	3	0.2	0.917

Table 8. Results of paired comparisons of some interesting variables. All results in additional materials.

Contrast	Estimate	SE	DF	t ratio	p value
herding breed - primitive breed	-0.06	0.033	986	-1.9	0.126
rural detached houses - urban apartment houses	-0.02	0.056	986	-0.3	0.991
detached – apartment	-0.05	0.047	986	-1.0	0.303
detached – terraced	0.91	0.049	986	18.7	**<.0001**
apartment – terraced	-0.05	0.054	986	-0.9	0.383
moves a lot - moves a little	-0.02	0.041	986	-0.6	0.566

Only age was statistically significantly associated with hyperactivity score ($F_{1,348}$=43.3; P=0.000) (Table 7). The mean hyperactivity in one-year-old dogs was 6.11 (95% CI: 5.52–6.79), while the mean hyperactivity in 10-year-old dogs was 3.63 (95% CI: 3.34–3.97). Age and impulsivity score were plotted in Figure 6.

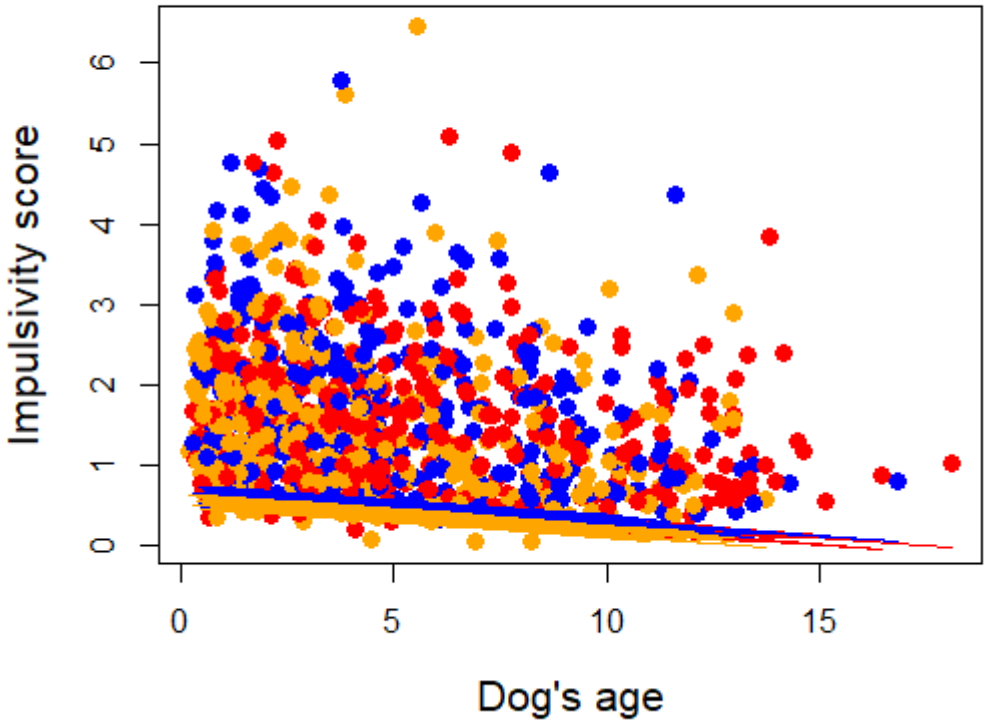

Figure 6. Impulsivity score as a function of the dog's age in years for dogs that were companion (in red), herding (in blue), or primitive (in orange). Lines show the predictions of a generalized linear model including the effect of breed group, sex, age, environment and activity. There was weak negative correlation between impulsivity score and dog's age (r=-0.21).

The figure illustrated that impulsivity score decreases as the age of the dog increases. Other independent variables were shown not to have a relation to impulsivity score. None of these

variables were statistically significant. Variable E level pair detached house – terraced house was significant. On average, dogs living in detached houses were shown to have smaller impulsivity score than those living in terraced houses.

3.3 Breed differences in environment-behaviour associations

3.3.1 Inattention

Environment-behaviour associations in companion, herding, and primitive breed group were compared using generalized linear model. Table 9 provided the results of four independent variables in each breed group and table 10 provided the comparisons among the most interesting levels of independent variables.

Table 9. Results from GLM (gamma distribution) comparing companion, herding, and primitive breed groups for environmental and lifestyle parameters for inattention score. Degrees of freedom (DF) for sex and age was 1, and for E and activity, DF was 3.

	Companion breed		Herding breed		Primitive breed	
	F	P	F	P	F	P
Sex	0.2	0.666	3.8	0.051	0.1	0.755
Age	3.3	0.069	7.2	**0.008**	2.4	0.123
E	1.7	0.173	2.1	0.103	0.5	0.714
Activity	1.5	0.222	0.8	0.498	1.1	0.366

Table 10. Results of paired comparisons of some interesting variables for all breed groups. All results in additional materials.

Contrast	Companion		Herding		Primitive	
	t ratio	p value	t ratio	p value	t ratio	p value
Female – male	-0.4	0.666	-2.0	0.051	-0.3	0.754
Rural detached - urban houses	-0.9	0.811	1.0	0.774	-0.9	0.827
Detached – apartment houses	-1.8	0.072	0.5	0.623	-0.8	0.440
Detached – terraced houses	10.5	**<.0001**	5.2	**<.0001**	22.0	**<.0001**
Apartment – terraced houses	0.6	0.533	-2.0	**0.047**	-0.2	0.850
Move a lot – moves a little	-2.0	**0.044**	-1.1	0.273	-0.1	0.901

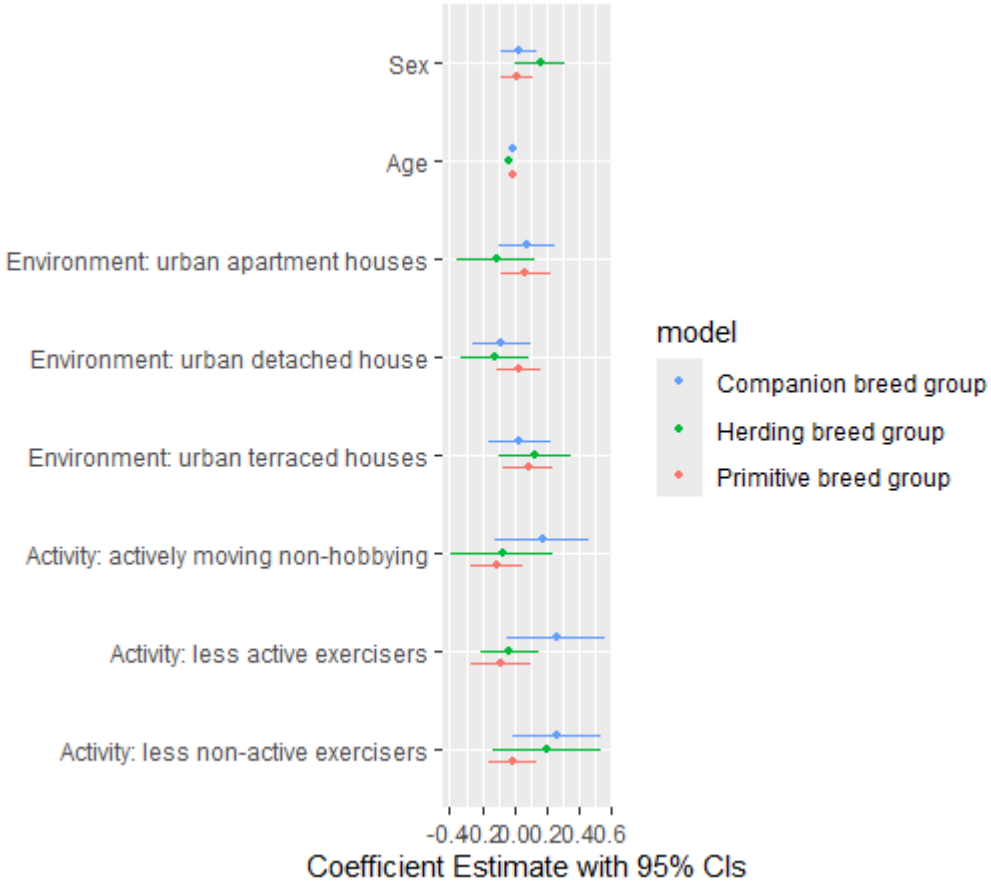

Figure 7. Coefficient plot of generalized linear model for inattention score. CI stands for confidence interval.

Age of the dog significantly predicted the inattention score among herding dogs with older dogs scoring lower than younger dogs, whereas activity level, housing type and sex were not significantly associated with inattention in this group of dogs (Table 9, Figure 7). In companion and primitive breeds, none of the predictors reached significance.

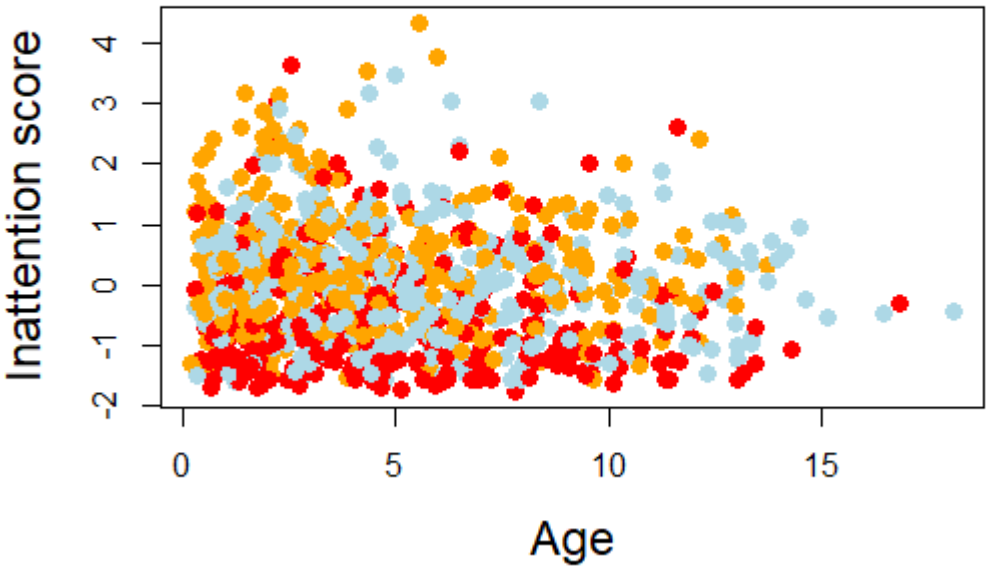

Figure 8. Inattention score plotted against age (in years) for dogs of companion (blue), herding (orange) and primitive breed (red) as indicated the respective coloration of the plotted dots. r=-0.14

In Fig. 8 there was a weak trend of decreasing inattention score as age is increasing. In this chart, there was a (rapid) decrease in inattention score after age of 12-13.

With significant increases in inattention score of the dogs that live in terraced house, lower inattention was observed among dogs that live in detached house, and among dogs in companion group that exhibited minimal exercise, as assessed by their owners. Different comparisons of living place showed no measurable effect on inattention score, except for apartment house – terraced house comparison in herding breed group. Dogs living in detached houses were consistently rated as more inattentive than those in terraced houses across all breed groups, but only in companion breed group was lower exercising significantly associated with higher inattention. (Table 10)

A comparison of the results of three breed groups revealed few significant differences. In summary, (based on) the responses of the dogs' informants selected for this study, age was related with inattention score only in the herding breed group, where older dogs were rated as less inattentive (β_1=-0.04; r=-0.14).

3.3.2 Impulsiveness

Generalized linear analysis was used to predict the impulsivity score. Figure 9 and table 11 compared the results obtained from the regression analysis of impulsivity score.

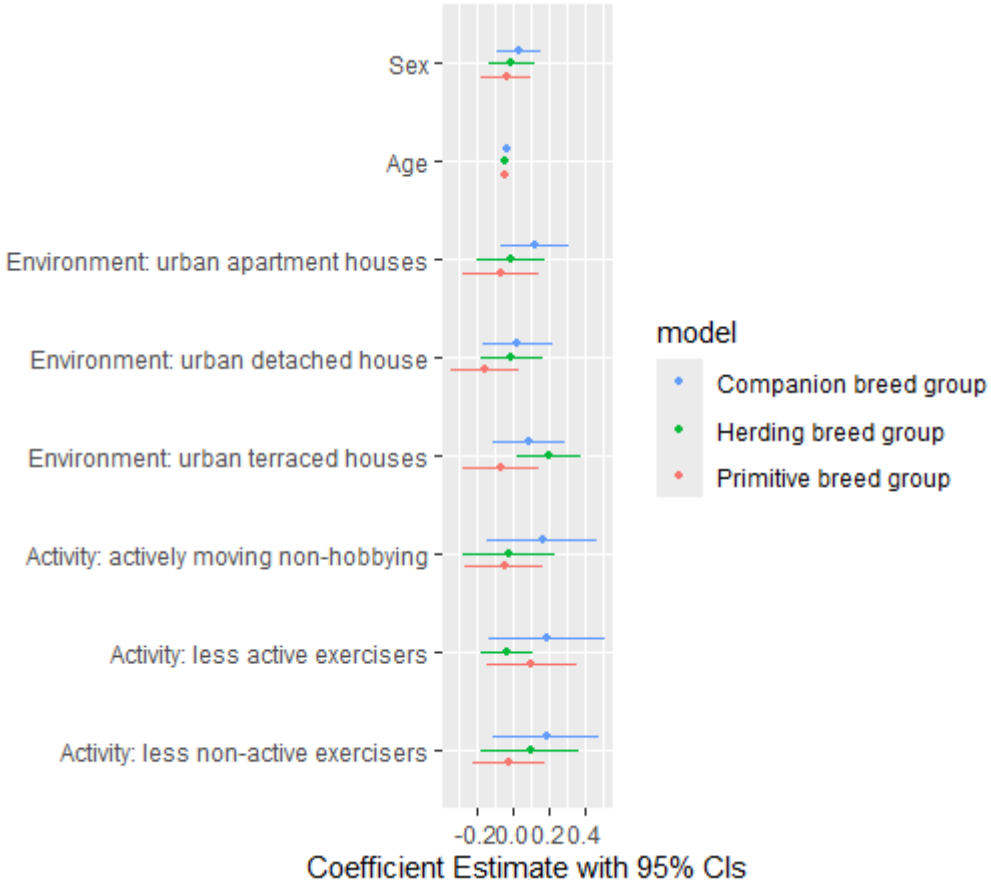

Figure 9. Coefficient plot of the results from generalized linear model of impulsivity score. CI stands for confidence interval.

Table 11. Results from GLM (gamma distribution) comparing companion, herding and primitive breed groups for environmental and lifestyle parameters for impulsivity score. DF for sex and age was 1, and for E and activity, DF was 3.

	Companion breed		Herding breed		Primitive breed	
	F	P	F	P	F	P
Sex	0.3	0.607	0.0	0.896	0.2	0.622
Age	13.9	**0.000**	14.8	**0.000**	17.6	**0.000**
E	0.9	0.460	2.6	**0.050**	0.9	0.451
Activity	0.5	0.676	0.4	0.774	0.6	0.601

It can be seen from the data in Table 11 that in all breed groups, age was significantly associated with hyperactivity/impulsivity, and that environment was significantly related for herding breed

group. The results obtained from the paired comparisons of independent variable was compared in Table 12.

Table 12. Results of paired comparisons of some interesting variables for all breed groups. All results in additional materials.

Contrast	Companion		Herding		Primitive	
	t ratio	p value	t ratio	p value	t ratio	p value
Female – male	-0.5	0.606	0.1	0.897	0.5	0.621
Rural detached – urban houses	-1.3	0.568	0.1	1.000	0.6	0.935
Detached - apartment houses	-1.6	0.117	0.1	0.946	-0.1	0.883
Detached - terraced houses	6.9	**<.0001**	11.1	**<.0001**	8.9	**<.0001**
Apartment – terraced houses	0.4	0.670	-2.2	**0.031**	0.0	0.984
Move a lot - move a little	-1.1	0.254	-0.4	0.662	-0.8	0.434

In the figure and tables, there was the general pattern of age being the most significant variable in all three breed groups, but environment being the most significant variable only in herding breed group. This result was significant at the $p = 0.05$ level. No evidence was found for linear associations between sex, environment, activity, and impulsivity score with other groups.

Following the comparison between detached and terraced houses, a significant increase ($p<0.0001$) in the impulsivity score was found in all breed groups, with dogs living in terraced houses exhibiting higher impulsivity than those in detached houses (estimated differences: 0.7 for companion breed group, 1.1 for herding breed group, and 0.8 for primitive breed group, respectively). When apartment house – terraced house was compared with impulsivity, no significant difference in companion breed group or primitive breed group were detected. Only herding breed group respondents living in terraced answered significantly that their dog was, on average, more impulsive than those living in apartment house.

4 Discussion

Previous reports have shown that certain demographic and environmental factors are associated with higher levels of impulsivity and inattention. In dogs, loneliness, male sex, and younger age have been linked to increased impulsivity and inattention (Sulkama et al. 2021). Similarly, in humans, impulsivity has been associated with, male sex (Gershon & Gershon 2002), adolescence (Casey et al. 2008), and aspects of urban environment. For example, urban living has been linked to higher rates of alcohol and drug dependence (Paykel et al. 2000), impulsivity and violence (Meyer-Lindenberg et al. 2006), and mood disorders (Peen et al. 2010). Urban environments may also affect stress processing (Lederbogen et al. 2011). On the other hand, regular physical exercise has been shown to reduce impulsivity (Zhang et al. 2022).

Objectives of the thesis was to find if inattention and impulsivity levels differ in different breed groups, does breed, living environment and lifestyle affect it, and are there breed differences in these environment-behaviour associations. To examine whether age, breed group and sex are associated with inattention and impulsivity, I hypothesized that younger dogs would exhibit higher levels of both traits, particularly in breeds historically selected for attentiveness, such as herding dogs. This prediction was based on prior findings that younger age is linked to increased impulsivity and inattention in both dogs and humans (Sulkama et al., 2021; Casey et al., 2008).

This study shows that breed group and age are significantly associated with inattention, where younger dogs showed higher inattention scores. It also shows that impulsivity was significantly related to age across all three breed groups—herding, companion, and primitive—with younger dogs consistently scoring higher. These findings align with Sulkama et al. (2021), who also reported age-related declines in impulsivity. Interestingly, living environment was significantly associated with impulsivity only in the herding breed group. Herding dogs living in terraced houses exhibited higher impulsivity scores than those in other housing types. In doing so, the study has demonstrated possible mismatch between the breed's evolutionary background—requiring space and attentiveness to subtle environmental cues—and the overstimulating or confined nature of urban environments (Lederbogen et al., 2011).

One interesting finding is that living environment—specifically the type of housing—has a measurable impact on both inattention and impulsivity. The most striking finding is that single-

family houses vs. terraced houses comparison emerge in all breed groups: dogs in single-family houses were estimated less inattentive and impulsive, while those in terraced or apartment houses were more so. What is surprising is that herding breed dogs in terraced houses are, on average, more impulsive than other breed groups in the same environment.

4.1 Breed-related differences in hyperactivity and inattentiveness

An initial objective of the project was to identify if dog breed is related to level of inattentiveness and impulsivity. As mentioned in the introduction, different dog breeds are widely bred for different purpose throughout prehistory.

It is interesting that breed group was significantly related to inattention but not to hyperactivity. Herding breeds, such as Border Collies and Australian Shepherds, showed the lowest inattention scores, likely due to their historical selection for attentiveness and responsiveness to human cues (for example, Border Collies are generally more impulsive (Fadet et al. 2016) but less inattentive (Turcsán, B. et al. 2011). Sulkama et al. showed border collie owners reported least inattention).

Interestingly, impulsivity scores were similar across all breed groups, suggesting that impulsivity may be less influenced by breed-specific traits and more by other factors such as age or environment. The lack of significant differences in hyperactivity between breed groups further supports this interpretation.

4.2 Differences between breeds groups on the context of environmental factors

Environmental factors, particularly housing type, were significantly associated with both inattention and impulsivity. Dogs living in detached houses were rated as less inattentive and impulsive than those in terraced or apartment housing. This pattern was consistent across all breed groups. One explanation may be that detached homes, often located in rural areas, provide less structured environments and fewer social interactions, which may reduce opportunities for behavioural regulation.

In herding breeds, impulsivity was also associated with living in terraced houses, possibly due to overstimulation in confined urban settings. Companion dogs showed a unique pattern: low physical activity was linked to higher inattention. This result has not been previously described directly, but it is aligned with findings that exercise benefits cognitive function in dogs (Lit et al., 2010; Kinsman et al., 2022).

Nevertheless, not all the results are like in the study of Sulkama et al (2021); the number of activities is not related to these features. This may be explained by the fact that my study had a smaller sample size, fewer explanatory variables and breeds, different environmental variables, and simpler connections in the model.

4.3 Results and evolutionary mismatch

The results partially support the evolutionary mismatch hypothesis. Herding breeds, bred for attentiveness and responsiveness in open environments, may struggle in urban settings with high sensory input. These dogs have been selectively bred for traits such as heightened vigilance and responsiveness to environmental cues (Jeong et al. 2025). These traits are advantageous in rural, working contexts but may lead to overstimulation in cities.

Similarly, certain breeds in companion group-often owned by less active individuals (e.g., brachycephalic breeds: Packer et al. 2020; small dogs: Coleman et al. 2008)-may experience under-stimulation, leading to inattentive behaviour. These breeds, while selected for sociability, still require mental and physical stimulation to maintain behavioural health.

These findings suggest that intrinsic factors like age may play a more significant role in certain behavioural and psychological traits than extrinsic factors like living environment and activity. This suggests that while environment matters, its effects may be breed-specific or moderated by other variables.

A possible explanation for the low inattention score observed in the herding breed group might be that these dogs have been bred to be highly attentive to detect changes in environment, such as possible dangers or threats. However, modern living environment may be mismatching to the EEA of herding and especially primitive breeds, as it presents array of human-made external stimuli. This kind of relation was found for herding breeds' environment and impulsivity. In addition, Finnish cities often include ample green spaces such as parks and forests, which may not be too different from the dogs EEA and explain why such relation was not found for primitive breed group.

4.4 Limitations of the study

This study considers environmental and behavioural associations in dogs but does not account for underlying genetic processes. It only looked at environmental and activity factors, and not genetic markers or longitudinal behavioural development and hence was not able to assess causality or the biological underpinnings.

An important caveat for interpreting my study is that I used categorized three breed groups, and three breeds in herding breed group is lower number than in other two groups. A relatively small number of breeds was used in this study due to its focus on effect of breed and evolution, and further research should be done with more breed-rich and with more different communities.

Another source of uncertainty is the selection bias in choosing only three breed groups, which do not necessarily represent evolutionarily old breeds, or breeds in breed groups were just not different enough. It is possible that these results may be attributable to the specific characteristics of the selected breed groups or to the lack of sufficient differentiation among the breeds within these groups, potentially due to the high degree of variability present within each breed group. There is a lot of gene flow between the groups, although there are genetically distinct groups found in dogs (Parker et al. 2017).

Estimation of behavioural traits and environmental influences was based on a number of assumptions. It was assumed that the selected breed groups adequately reflected meaningful evolutionary roles. A second assumption was that the survey questions accurately captured the constructs of inattention and impulsivity. Third, I assumed that owners interpreted and reported their dogs' behaviour, activity levels, and living environments consistently. Fourth, my calculations apply to the Finnish context, where urban areas are relatively rural compared to other countries. What is clear is that these assumptions, while necessary for analysis, may have introduced variability and limited the generalizability of the findings.

One inherent weakness of this study is its restricted temporal geographical relevance. Data were collected through a single questionnaire administered in Finland, with only two options provided for describing the dog's living environment. This limited the environmental granularity

and may have constrained the inferences that can be drawn about the broader effects of urbanization or rural living.

The studies by Puurunen et al. (2020), Sulkama et al. (2021) and Martinez et al. (2022) were the only ones published this far indicating a positive association between behaviour and modern living environments. In these studies, the environment definition conditions may have included different definitions of activity, hyperactivity, inattentiveness, rural environment and urban environment. My study tried to eliminate multicollinearity and overfitting so that under E variable there were both living place and living environment, and for activity variable, daily exercise and hobby frequency so that it would limit factors under the living conditions.

A number of questions remain unanswered, such as why the interaction was not detected at all three breed groups with activity or environment. It is obvious, however, that studying global human-made environment changes is essential, as the evolutionary responses to changes are likely not fast nor evident to observe from other factors.

One possible explanation for these results is the very large genetic diversity of dog breeds. For example, DRD4 acts as a dopamine sensor that switches host metabolism during stress or energy-demanding states via mechanisms involving dopamine signalling and neural plasticity. These features can be different among different dog breeds, so DRD4 is an attractive target for studying or treating attention-related and impulsivity disorders. Inconsistency between the breeds for inattention could be attributed to breed-specific factors or owners' subjectivity ideas of behaviour, living environment, exercise and hobbies, related to how age impacts behaviour only on herding dogs. It may be that some participants answered more strictly for questions about impulsivity since mean ages for dogs in all breed groups are quite similar, or simply that dog breeds are genetically very different.

The surprising result that inattention or impulsivity was not related to living environment or activity may be related to the fact there were only two options to choose for living place, and to dog owners' subjective idea of what is defined as urban and rural living environment, especially considering that Finnish cities are very rural; in practice, there are no large metropolitan areas in Finland. Moreover, such a dichotomous division of the environment into two categories is a really simplified description of the habitat. It is known that older dogs are more indoors (Ley et al. 2009), which may have affected the results. Similarly, the owner's estimate of the

amount of exercise or definition of hobby is not necessarily accurate and does not reflect how much activity or stimulus the dog gets; hobby variable groups all hobbies together, although different hobbies have likely difference effects.

Secondly, owners of the selected breeds may have assessed their dogs' behaviour using different criteria, influenced by breed-specific expectations (e.g., impulsivity in companion dogs versus herding dogs), or by the nature of the owner's experience of different breeds, owning dog in general, and their underlying motivations regarding different breeds. For example, only 14% of owners of companion dogs were stated their living environment as "rural", and 85% of herding dogs have active hobby frequency. This points out that certain types of owners own certain breeds of dogs. In addition, it is possible that older dogs are more likely to be found in environments that align with their reduced activity levels.

A particular strength of this study is the use of a nationwide dog owner-based dataset that provides a sufficient sample size and statistical power (except for t-test of companion breed and primitive breed for inattention, t-test for impulsivity, and primitive breed group in generalized linear model; see tables 19-21) to explore the association between breed groups, environment, activity and ADHD-like behaviour. Nevertheless, some limitations to my study should be addressed. First, inattention and impulsivity, which rely on owners claims and questions by Salonen et al. 2021, may be less precise than those made according to different criteria/questions or by veterinarian. This is a major limitation of this study compared with previous studies that different inattentiveness and impulsivity standards of dogs.

Although more information regarding the relative impacts of environment and other factors such as diet, lifestyle, and exercise, is important, it is unlikely to resolve all of the tension and debate about the appropriateness of these variables in explaining attention-related behaviours. Further research in developed and developing countries will improve our understanding of how modern environments affect cognition and behaviour. This should include studies examining the genes of people migrating to developed countries, longitudinal behavioural development, and more detailed environmental modelling. Also, there is a need for more detailed modelling of evolutionary perspective, as has recently been conducted in schizophrenia and autism spectrum disorder.

5 Conclusions

This study set out to predict which environmental features were related to inattention and impulsivity of dogs on three breed groups. This study has identified owner-reported behavioural features has clear environmental relations. Breed was associated to inattention but not with impulsivity. Age significantly influenced inattention and impulsivity scores across all models, with older dogs exhibiting lower levels of inattention and impulsivity. The living environment was associated with increased impulsiveness in herding breeds, particularly those residing in terraced houses. Additionally, living in detached houses was correlated with both high inattention and impulsivity across all three breed groups. Minimal physical activity was linked to higher inattention in companion dogs.

The results of this study indicate that the purpose for which the dog breed has been bred may play a significant role in inattentiveness, but not in impulsiveness, regarding this small sample and these breed groups, and it is also possible that the differences between the breeds are just big even within these breed groups. These results also suggest that inattention was related to age only in herding breed, but impulsivity was related to age in all three breed groups and to living environment in herding breed group. It is possible that herding dog breeds are more exposed to inattention disorders because these are bred to attend to distractions, which are common in urban environment. Similarly, dogs may not have fully adapted to living in detached houses, which could explain the significant relationship between inattention/impulsiveness and the detached versus terraced house living arrangement across all three breed groups.

The results obtained in this study clearly demonstrated that substantial variability exists in inattention across dog breed groups. This trait appears to be a good candidate for consideration in selective breeding programs, particularly for working breeds where attentiveness is a desired trait.

Future studies should incorporate more diverse dog breeds, longitudinal designs, and objective behavioural assessments to better understand the causal relationships between environment, activity, and attention-related traits in dogs and humans. Considerably more work will need to be done to determine how specific environmental factors—such as urban noise, social exposure, and housing density—interact with breed-specific predispositions to influence impulsivity and

inattention. Other types of environmental classification would include quantitative urbanity indices based on geographic data, or detailed measures of social and physical stimulation, such as time spent outdoors, interaction with other dogs or humans, or exposure to novel stimuli. Continued efforts are needed to make standardized behavioural assessment tools more accessible to researchers, veterinarians, psychiatrists, dog owners and people with ADHD, in order to improve the reliability and comparability of studies on cognition and behaviour.

Acknowledgements

Thanks to all the teachers and supervisors whose lectures on evolution, statistic models, evolutionary psychology and animal behaviour have been inspiring. In particular I appreciate Milla Salonen and Virpi Lummaa for their invaluable contributions, feedback and comments including guidance on improving academic writing and presenting, analyses, tables, and figures in a in such a way that they do justice to the results.

I want to thank specifically Milla, for her assistance and instruction to get me started in the face of a large amount of data. Also, I am grateful to her, Hannes Lohi and the entire research group, for providing me access to the data they collected, as well as every dog owner who participated in the survey.

I'm deeply thankful to my family for their support and patience. Finally, I would like to thank my dear wife for continuous support, encouragement, and commentary. Your constant belief that this thesis would be completed has been motivating.

References

Ahmeti-Pronaj, A., Uka, A., & Isufi, L. (2025). The Urban Battlefield of The Mind: Environmental Influence on ADHD And Executive Functions in Adolescents. *Georgian Medical News*, *360*, 76.

American Psychiatric Association (2013) Attention-Deficit/Hyperactivity Disorder. *Diagnostic and Statistical Manual of Mental Disorders: DSM-5.* 5th ed., American Psychiatric Publishing.

Braubach, M, Savelsberg, J & World Health Organization. Regional Office for Europe (2009). Social inequalities and their influence on housing risk factors and health: a data report based on the WHO LARES database. World Health Organization. Regional Office for Europe. https://iris.who.int/handle/10665/107955

Biederman, J., & Faraone, S. V. (2006). The effects of attention-deficit/hyperactivity disorder on employment and household income. *MedGenMed: Medscape general medicine*, *8*(3), 12. https://www.scopus.com/inward/record.uri?eid=2-s2.0-33746594791&partnerID=40&md5=46ad4f1ba61ded96ef2f647437511d92.

Brikell, I., Kuja-Halkola, R., & Larsson, H. (2015) Heritability of attention-deficit hyperactivity disorder in adults. *American journal of medical genetics. Part B, Neuropsychiatric genetics*. [Online] 168B (6), 406–413.

Boix, F., Qiao, S., Kolpus, T., & Sagvolden, T. (1998) Chronic l-deprenyl treatment alters brain monoamine levels and reduces impulsiveness in an animal model of Attention-Deficit/Hyperactivity Disorder. *Behavioural brain research*. [Online] 94 (1), 153–162.

Casey, B., Nigg, J. T., & Durston, S. (2007). New potential leads in the biology and treatment of attention deficit-hyperactivity disorder. *Current Opinion in Neurology*, *20*(2), 119–124. https://doi.org/10.1097/WCO.0b013e3280a02f78

Casey, B. J., Getz, S., & Galvan, A. (2008). The adolescent brain. *Developmental Review*, *28*(1), 62–77. https://doi.org/10.1016/j.dr.2007.08.003 Web.

Chaudhary, N., & Salali, G. (2022) Hunter-Gatherers, Mismatch and Mental Disorder. *Evolutionary Psychiatry: Current Perspectives on Evolution and Mental Health* (pp. 64-83). Ed. Riadh Abed and Paul St John-Smith. 1st ed. Cambridge: Cambridge University Press. Print. doi:10.1017/9781009030564.007.

Cicchetti, D. V. (1994) Guidelines, Criteria, and Rules of Thumb for Evaluating Normed and Standardized Assessment Instruments in Psychology. *Psychological assessment*. [Online] 6 (4), 284–290.

Coleman, K. J., Rosenberg, D. E., Conway, T. L., Sallis, J. F., Saelens, B. E., Frank, L. D., & Cain, K. (2008) Physical activity, weight status, and neighborhood characteristics of dog walkers. *Preventive medicine*. [Online] 47 (3), 309–312.

Del-Ponte, B., Quinte, G. C., Cruz, S., Grellert, M., & Santos, I. S. (2019) Dietary patterns and attention deficit/hyperactivity disorder (ADHD): A systematic review and meta-analysis. *Journal of affective disorders*. [Online] 252160–173.

Diagnostic and Statistical Manual of Mental Disorders: DSM-5. (2013) 5th ed. Washington (D.C.): American Psychiatric Publishing. Print.

Dutrow, E. V., Serpell, J. A., & Ostrander, E. A. (2022) Domestic dog lineages reveal genetic drivers of behavioral diversification. *Cell*. [Online] 185 (25), 4737-4755.e18.

Fadel, F. R., Driscoll, P., Pilot, M., Wright, H., Zulch, H., & Mills, D. (2016) Differences in Trait Impulsivity Indicate Diversification of Dog Breeds into Working and Show Lines. *Scientific reports*. [Online] 6 (1).

Faraone, S. V. & Larsson, H. (2019) Genetics of attention deficit hyperactivity disorder. *Molecular psychiatry*. [Online] 24 (4), 562–575. Web.

Faraone, S. V., Banaschewski, T., Coghill, D., Zheng, Y., Biederman, J., Bellgrove, M. A., Newcorn, J. H., Gignac, M., Al Saud, N. M., Manor, I., Rohde, L. A., Yang, L., Cortese, S., Almagor, D., Stein, M. A., Albatti, T. H., Aljoudi, H. F., Alqahtani, M. M. J., Asherson, P., … Wang, Y. (2021) The World Federation of ADHD International Consensus Statement: 208 Evidence-based conclusions about the disorder. *Neuroscience and biobehavioral reviews*. [Online] 128789–818. Web.

Freedman, A. H., Gronau, I., Schweizer, R. M., Ortega-Del Vecchyo, D., Han, E., Silva, P. M., Galaverni, M., Fan, Z., Marx, P., Lorente-Galdos, B., Beale, H., Ramirez, O., Hormozdiari, F., Alkan, C., Vilà, C., Squire, K., Geffen, E., Kusak, J., Boyko, A. R., … Novembre, J. (2014) Genome Sequencing Highlights the Dynamic Early History of Dogs. *PLoS genetics*. [Online] 10 (1).

Gallo, E. F. & Posner, J. (2016) Moving towards causality in attention-deficit hyperactivity disorder: overview of neural and genetic mechanisms. *The Lancet. Psychiatry*. [Online] 3 (6), 555–567.

García de Jalón, S., Chiabai, A., Quiroga, S., Suárez, C., Ščasný, M., Máca, V., Zvěřinová, I., Marques, S., Craveiro, D., & Taylor, T. (2021) The influence of urban greenspaces on people's physical activity: A population-based study in Spain. *Landscape and urban planning*. [Online] 215.

Gershon, J & Gershon, Jonathan (2002) A Meta-Analytic Review of Gender Differences in ADHD. *Journal of attention disorders*. [Online] 5 (3), 143–154.

González-Martínez, Á., Muñiz de Miguel, S., Graña, N., Costas, X., & Diéguez, F. J. (2023) Serotonin and Dopamine Blood Levels in ADHD-Like Dogs. *Animals (Basel)*. [Online] 13 (6), 1037.

Hale, J.B., Reddy, L.A., Weissman, A.S., Lukie, C., Schneider, A.N. (2013) Integrated neuropsychological assessment and intervention for youth with attention-deficit/hyperactivity disorder. *Neuropsychological assessment and intervention for youth: An evidence-based approach to emotional and behavioral disorders.* L. A. Reddy, A. S. Weissman, & J. B. Hale (Eds.), Washington, DC: APA Press

Hytönen, M. K. & Lohi, H. (2016) Canine models of human rare disorders. *Rare diseases (Austin, Tex.)*. [Online] 4 (1), e1241362–e1241362. Web.

Jeong, H., Ostrander, E. A., & Kim, J. (2025) Genomic evidence for behavioral adaptation of herding dogs. *Science advances*. [Online] 11 (18), eadp4591.

Kaur B., Kaur J., Kashyap N., Arora J.S., Mukhopadhyay C.S. (2023) A comprehensive review of genomic perspectives of canine diseases as a model to study human disorders. *Canadian*

Journal of Veterinary Research, 87 (1), pp. 3 - 8, https://www.scopus.com/inward/record.uri?eid=2-s2.0-85145645752&partnerID=40&md5=7d1f800bbfdbccc0b49055bda582a9b3.

Kim, D., Yadav, D., & Song, M. (2024) An updated review on animal models to study attention-deficit hyperactivity disorder. *Translational Psychiatry*, *14*(1), Article 187. https://doi.org/10.1038/s41398-024-02893-0

Kinsman, R. H., Main, K. E., Casey, R. A., Da Costa, R. E. P., Owczarczak-Garstecka, S. C., Knowles, T. G., Tasker, S., & Murray, J. K. (2022) Dog Walk frequency and duration: Analysis of a cohort of dogs up to 15 months of age. *Applied animal behaviour science*. [Online] 250.

Klein, M., Onnink, M., van Donkelaar, M., Wolfers, T., Harich, B., Shi, Y., Dammers, J., Arias-Vásquez, A., Hoogman, M., & Franke, B. (2017) Brain Imaging Genetics in ADHD and Beyond – Mapping Pathways from Gene to Disorder at Different Levels of Complexity. *Neuroscience and biobehavioral reviews 80* 115–155. Web.

Konno, A., Romero, T., Inoue-Murayama, M., Saito, A., & Hasegawa, T. (2016) Dog Breed Differences in Visual Communication with Humans. *PloS one*. [Online] 11 (10), e0164760.

Kozyra, M., Zimnicki, P., Kaczerska, J., Śmiech, N., Nowińska, M., & Milanowska, J. (2020) Relationship between the diet and psychiatric diseases such as depression, anxiety and attention-deficit hyperactivity disorder (ADHD). *Journal of education, health and sport*. [Online] 10 (8), 93–104. https://doi.org/10.12775/JEHS.2020.10.08.011.

Kovács, T., Reicher, V., Csibra, B., & Gácsi, M. (2024) More inattentive dogs benefit from repetitive but not permissive training. *Applied animal behaviour science*. [Online] 281.

Le Cunff, A.-L. (2024). Distractibility and Impulsivity in ADHD as an Evolutionary Mismatch of High Trait Curiosity. *Evolutionary Psychological Science*, *10*(3), 282–297. https://doi.org/10.1007/s40806-024-00400-8

LeBlanc, J. C. (2021) "Impact of COVID-19 on lifestyle habits and mental health symptoms in children with attention-deficit/hyperactivity disorder in Canada": Can we trust the numbers from this Internet survey? *Paediatrics & child health*. [Online] 26 (7), 442–442. https://doi.org/10.1093/pch/pxab059.

Lederbogen, F., Kirsch, P., Haddad, L., Streit, F., Tost, H., Schuch, P., Wüst, S., Pruessner, J. C., Rietschel, M., Deuschle, M., & Meyer-Lindenberg, A. (2011) City living and urban upbringing affect neural social stress processing in humans. *Nature (London)*. [Online] 474 (7352), 498–501.

Ley, J. M., Bennett, P. C., & Coleman, G. J. (2009). A refinement and validation of the Monash Canine Personality Questionnaire (MCPQ). *Applied Animal Behaviour Science*, *116*(2), 220–227. https://doi.org/10.1016/j.applanim.2008.09.009

Li, W.-L., Liu, Y.-H., Li, J.-X., Ding, M.-T., Adeola, A. C., Isakova, J., Aldashev, A. A., Peng, M.-S., Huang, X., Xie, G., Chen, X., Yang, W.-K., Zhou, W.-W., Ghanatsaman, Z. A., Olaogun, S. C., Sanke, O. J., Dawuda, P. M., Hytönen, M. K., Lohi, H., … Zhang, Y.-P. (2023) Multiple Origins and Genomic Basis of Complex Traits in Sighthounds. *Molecular biology and evolution*. [Online] 40 (8).

Lit, L., Schweitzer, J. B., Iosif, A.-M., & Oberbauer, A. M. (2010). Owner reports of attention, activity, and impulsivity in dogs: a replication study. *Behavioral and Brain Functions*, *6*(1), 1–1. https://doi.org/10.1186/1744-9081-6-1. Web.

Litwin, Mark S. *How to Assess and Interpret Survey Psychometrics*. 2nd ed. Thousand Oaks, Calif.; SAGE, 2003. Print.

López-Hernández, A. E., Miquel-López, C., García-Medina, J. J., & García-Ayuso, D. (2024) 'Vision-related quality of life and near-work visual symptoms in patients with attention-deficit/hyperactivity disorder', *Clinical and Experimental Optometry*, 108(7), pp. 830–837. Doi: 10.1080/08164622.2024.2422473.

MacLean, E. L., Snyder-Mackler, N., vonHoldt, B. M., & Serpell, J. A. (2019) Highly heritable and functionally relevant breed differences in dog behaviour. *Proceedings of the Royal Society B: Biological Sciences*. [Online] 286 (1912).

Majdak, P., Ossyra, J. R., Ossyra, J. M., Cobert, A. J., Hofmann, G. C., Tse, S., Panozzo, B., Grogan, E. L., Sorokina, A., & Rhodes, J. S. (2016) A new mouse model of ADHD for medication development. *Scientific reports*. [Online] 6 (1).

Martinez, E., Cesário, C. S., Ferraz, F., Repolês, R., Silva, I. O., & Boere, V. (2022) Behavior of rural and urban free-ranging dogs in Viçosa, Minas Gerais, Brazil. *Journal of veterinary behavior*. [Online] 4868–73.

Mattos, P., Moraes, C. E. F. de, Sichieri, R., Hay, P., Faraone, S. V., & Appolinario, J. C. (2024) Adult ADHD Symptoms in a Large Metropolitan Area from Brazil: Prevalence and Associations with Psychiatric Comorbidity, Bullying, Sexual Abuse, and Quality of Life. *Journal of attention disorders*. [Online] 28 (7), 1082–1091.

Meyer-Lindenberg, A., Buckholtz, J. W., Kolachana, B., Hariri, A. R., Pezawas, L., Blasi, G., Wabnitz, A., Honea, R., Verchinski, B., Callicott, J. H., Egan, M., Mattay, V., & Weinberger, D. R. (2006) Neural Mechanisms of Genetic Risk for Impulsivity and Violence in Humans. *Proceedings of the National Academy of Sciences - PNAS*. [Online] 103 (16), 6269–6274.

Miklosi, A, Topal J, & Csanyi, V. (2004) Comparative social cognition: what can dogs teach us? *Animal behaviour*. [Online] 67 (6), 995–1004.

National Institutes of Health (2024) Attention-Deficit/Hyperactivity Disorder: What You Need to Know. <https://www.nimh.nih.gov/health/publications/attention-deficit-hyperactivity-disorder-what-you-need-to-know> [Read 19.4.2025]

Nikolas, M.A., & Burt S.A. (2010) Genetic and Environmental Influences on ADHD Symptom Dimensions of Inattention and Hyperactivity: A Meta-Analysis. *Journal of abnormal psychology* (1965) 119.1 1–17. Web.

O'Rourke, A., Haydock, R., Butterwick, R. F., German, A. J., Carson, A., Lyle, S., & O'Flynn, C. (2025) Estimated activity levels in dogs at population scale with linear and causal modeling. *Frontiers in veterinary science*. [Online] 12.

Packer, R. M. A., O'Neill, D. G., Fletcher, F., & Farnworth, M. J. (2020) Come for the looks, stay for the personality? A mixed methods investigation of reacquisition and owner recommendation of Bulldogs, French Bulldogs and Pugs. *PloS one*. [Online] 15 (8).

Parker, H. G., Dreger, D. L., Rimbault, M., Davis, B. W., Mullen, A. B., Carpintero-Ramirez, G., & Ostrander, E. A. (2017) Genomic Analyses Reveal the Influence of Geographic Origin, Migration, and Hybridization on Modern Dog Breed Development. *Cell reports (Cambridge)*. [Online] 19 (4), 697–708.

Paykel, E. S., Abbott, R., Jenkins, R., Brugha, T. S., & Meltzer, H. (2000). Urban–rural mental health differences in Great Britain: findings from the National Morbidity Survey. *Psychological Medicine*, *30*(2), 269–280. https://doi.org/10.1017/S003329179900183X

Peen, J., Schoevers, R. A., Beekman, A. T., & Dekker, J. (2010) The Current Status of Urban-Rural Differences in Psychiatric Disorders. *Acta psychiatrica Scandinavica* 121.2 84–93. Web.

Pelsser, L. M., Frankena, K., Toorman, J., & Rodrigues Pereira, R. (2017). Diet and ADHD, reviewing the evidence: A systematic review of meta-analyses of double-blind placebo-controlled trials evaluating the efficacy of diet interventions on the behavior of children with ADHD. *PloS One*, *12*(1), e0169277-. https://doi.org/10.1371/journal.pone.0169277

Puurunen, J., Sulkama, S., Tiira, K., Araujo, C., Lehtonen, M., Hanhineva, K., & Lohi, H. (2016) A non-targeted metabolite profiling pilot study suggests that tryptophan and lipid metabolisms are linked with ADHD-like behaviours in dogs. *Behavioral and brain functions*. [Online] 12 (1).

Puurunen, J., Hakanen, E., Salonen, M. K., Mikkola, S., Sulkama, S., Araujo, C., & Lohi, H. (2020) Inadequate socialisation, inactivity, and urban living environment are associated with social fearfulness in pet dogs. *Scientific reports*. [Online] 10 (1).

Regan, S. L., Williams, M. T., & Vorhees, C. V. (2022) Review of rodent models of attention deficit hyperactivity disorder. *Neuroscience and biobehavioral reviews*. [Online] 132621–637.

Rommel, A.-S., Halperin, J. M., Mill, J., Asherson, P., & Kuntsi, J. (2013) Protection from Genetic Diathesis in Attention-Deficit/Hyperactivity Disorder: Possible Complementary Roles of Exercise. *Journal of the American Academy of Child and Adolescent Psychiatry*. [Online] 52 (9), 900–910.

Russell VA, Sagvolden T, & Johansen E. B (2005) Animal models of attention-deficit hyperactivity disorder. *Behavioral and brain functions*. [Online] 1 (1).

Salonen, M., Sulkama, S., Mikkola, S., Puurunen, J., Hakanen, E., Tiira, K., Araujo, C., & Lohi, H. (2020) Prevalence, comorbidity, and breed differences in canine anxiety in 13,700 Finnish pet dogs. *Scientific reports*. [Online] 10 (1).

Salonen, M., Mikkola, S., Hakanen, E., Sulkama, S., Puurunen, J., & Lohi, H. (2021) Reliability and Validity of a Dog Personality and Unwanted Behavior Survey. *Animals (Basel)*. [Online] 11 (5), 1234.

Sayal, K., Prasad, V., Daley, D., Ford, T., & Coghill, D. (2018) ADHD in Children and Young People: Prevalence, Care Pathways, and Service Provision. *The Lancet. Psychiatry* 5.2: 175–186. Web.

Shaw, P., Stringaris, A., Nigg, J., & Leibenluft, E. (2014) Emotion Dysregulation in Attention Deficit Hyperactivity Disorder. *The American journal of psychiatry*. [Online] 171 (3), 276–293. https://doi.org/10.1176/appi.ajp.2013.13070966.

Siddique, S., Banerjee, M., Ray, M. R., & Lahiri, T. (2011) Attention-deficit hyperactivity disorder in children chronically exposed to high level of vehicular pollution. *European journal of pediatrics*. [Online] 170 (7), 923–929.

Sinn, N. (2008) Nutritional and dietary influences on attention deficit hyperactivity disorder. *Nutrition reviews*. [Online] 66 (10), 558–568. https://doi.org/10.1111/j.1753-4887.2008.00107.x.

Smith, B. P., Browne, M., & Serpell, J. A. (2017) Owner-reported behavioural characteristics of dingoes (Canis dingo) living as companion animals: A comparison to 'modern' and 'ancient' dog breeds. *Applied animal behaviour science*. [Online] 18777–84.

Smith, T. A., Srikanth, K., & Huson, H. J. (2024) Comparative Population Genomics of Arctic Sled Dogs Reveals a Deep and Complex History. *Genome biology and evolution*. [Online] 16 (9).

Soler-Gutiérrez, A., Pérez-González, J. & Mayas, J. (2023) Evidence of emotion dysregulation as a core symptom of adult ADHD: A systematic review. *PloS one*. [Online] 18 (1), e0280131.

Stevens, L. J., Kuczek, T., Burgess, J. R., Hurt, E., & Arnold, L. E. (2011) Dietary Sensitivities and ADHD Symptoms: Thirty-five Years of Research. *Clinical pediatrics*. [Online] 50 (4), 279–293.

Sulkama, S., Puurunen, J., Salonen, M., Mikkola, S., Hakanen, E., Araujo, C., & Lohi, H. (2021) Canine hyperactivity, impulsivity, and inattention share similar demographic risk factors and behavioural comorbidities with human ADHD. *Translational psychiatry*. [Online] 11 (1). https://doi.org/10.1038/s41398-021-01626-x

Sulkama, S. (2023) *Risk factors of canine ADHD-like and repetitive behaviour*. Helsinki: University of Helsinki.

Swanepoel, A., Music, G., Launer, J., & Reiss, M. J. (2017) How Evolutionary Thinking Can Help Us to Understand ADHD. *BJPsych advances* 23.6 410–418. Web.

The Centers for Disease Control and Prevention. About Attention-Deficit / Hyperactivity Disorder (ADHD) (2024). <https://www.cdc.gov/adhd/about/index.html#:~:text=Key%20points%201%20ADHD%20is%20one%20of%20the,involve%20a%20combination%20of%20behavior%20therapy%20and%20medication.> [Read 19.4.2025)

Thapar, A., Cooper, M., Eyre, O., & Langley, K. (2013) Practitioner Review: What Have We Learnt About the Causes of ADHD?" *Journal of child psychology and psychiatry* 54.1: 3–16. Web.

Turcsán, B., Kubinyi, E., & Miklósi, Á. (2011). Trainability and boldness traits differ between dog breed clusters based on conventional breed categories and genetic relatedness. *Applied Animal Behaviour Science*, *132*(1), 61–70. https://doi.org/10.1016/j.applanim.2011.03.006

Vas, J., Topál, J., Péch, É., & Miklósi, Á. (2007) Measuring attention deficit and activity in dogs: A new application and validation of a human ADHD questionnaire. *Applied animal behaviour science*. [Online] 103 (1), 105–117. https://doi.org/10.1016/j.applanim.2006.03.017

Wan, M., Hejjas, K., Ronai, Z., Elek, Z., Sasvari-Szekely, M., Champagne, F. A., Miklósi, Á., & Kubinyi, E. (2013) DRD4 and TH Gene Polymorphisms Are Associated with Activity, Impulsivity and Inattention in Siberian Husky Dogs. *Animal genetics.* 44 (6) 717–727. Web.

Williams, J., & Taylor, E. (2006) The evolution of hyperactivity, impulsivity and cognitive diversity. *Journal of the Royal Society, Interface*, *3*(8), 399–413. https://doi.org/10.1098/rsif.2005.0102

Wu, Y.-T., Prina, A., Jones, A., Barnes, L., Matthews, F., Brayne, C., & MRC CFAS. (2017) Micro-Scale Environment and Mental Health in Later Life: Results from the Cognitive Function and Ageing Study II (CFAS II). *Journal of affective disorders* 218 359–364. Web.

Yang, H., Wang, G., Wang, M., Ma, Y., Yin, T., Fan, R., Wu, H., Zhong, L., Irwin, D. M., Zhai, W., & Zhang, Y. (2017) The origin of chow chows in the light of the East Asian breeds. *BMC genomics*. [Online] 18 (1).

Yuchi, W., Brauer, M., Czekajlo, A., Davies, H. W., Davis, Z., Guhn, M., Jarvis, I., Jerrett, M., Nesbitt, L., Oberlander, T. F., Sbihi, H., Su, J., & van den Bosch, M. (2022) Neighborhood environmental exposures and incidence of attention deficit/hyperactivity disorder: A population-based cohort study. *Environment international*. [Online] 161.

Zang, Y. (2019) Impact of physical exercise on children with attention deficit hyperactivity disorders: Evidence through a meta-analysis. *Medicine (Baltimore),* 98(46), p.e17980. https://doi.org/10.1097/MD.0000000000017980

Zapata, I., Lilly, M. L., Herron, M. E., Serpell, J. A., & Alvarez, C. E. (2022) Genetic testing of dogs predicts problem behaviors in clinical and nonclinical samples. *BMC genomics*. [Online] 23 (1).

Zhang, Y., Chen, L., Jiang, X., & Bőthe, B. (2022) Investigating the Associations of ADHD Symptoms, Impulsivity, Physical Exercise, and Problematic Pornography Use in a Chinese Sample. *International journal of environmental research and public health*. [Online] 19 (22), 15221.

Zhang, Y., Hu, B. & Zhang, Y.-P. (2020) Research progress on the role of nutritional supplements in the treatment of attention deficit hyperactivity disorder in children [营养补充剂治疗儿童注意缺陷多动障碍的研究进展]. *Zhongguo Ertong Baojian Zazhi*, 28(12), pp.1351–1354. http://cjchc.xjtu.edu.cn/EN/10.11852/zgetbjzz2019-1444

Appendices

Appendix 1 Frequency table of variables of three breed groups

Table 13. Variable observations for three dog breed groups. "E" stands for environment.

		Companion breed	Herding breed	Primitive breed
Sex	Female	177	167	150
	Male	175	151	177
Age	0-3	128	129	163
	4-6	103	95	84
	7-9	62	63	50
	10-12	36	25	25
	13-15	21	5	5
	16-18	2	1	0
E	Rural detached houses	49	97	87
	Urban apartment houses	127	61	72
	Urban detached houses	96	80	95
	Urban terraced houses	80	80	73
Activity	Actively moving and engaging	16	119	58
	Actively moving non-hobby	71	25	81
	Less active exercisers	46	151	51

Less non-active exercisers	219	23	137
Total number	352	318	327
Proportion	35%	32%	33%

Appendix 2 Frequency table of variables (in percentage terms)

Table 14. Proportions of variables for three dog breed groups.

		Companion breed	Herding breed	Primitive breed
Sex	Female	50 %	53 %	46 %
	Male	50 %	47 %	54 %
Age	0–3	36 %	41 %	50 %
	4–6	29 %	30 %	26 %
	7–9	18 %	20 %	15 %
	10–12	10 %	8 %	8 %
	13–15	6 %	2 %	2 %
	16–18	1 %	0 %	0 %
E	Rural detached houses	14 %	15 %	27 %
	Urban apartment houses	36 %	19 %	22 %
	Urban detached houses	27 %	25 %	29 %
	Urban terraced houses	23 %	25 %	22 %
Activity	Actively moving and engaging	5 %	37 %	18 %
	Actively moving non-hobby	20 %	8 %	25 %
	Less active exercisers	13 %	14 %	16 %
	Less non-active exercisers	62 %	7 %	42 %

Appendix 3 Plots for GLM models

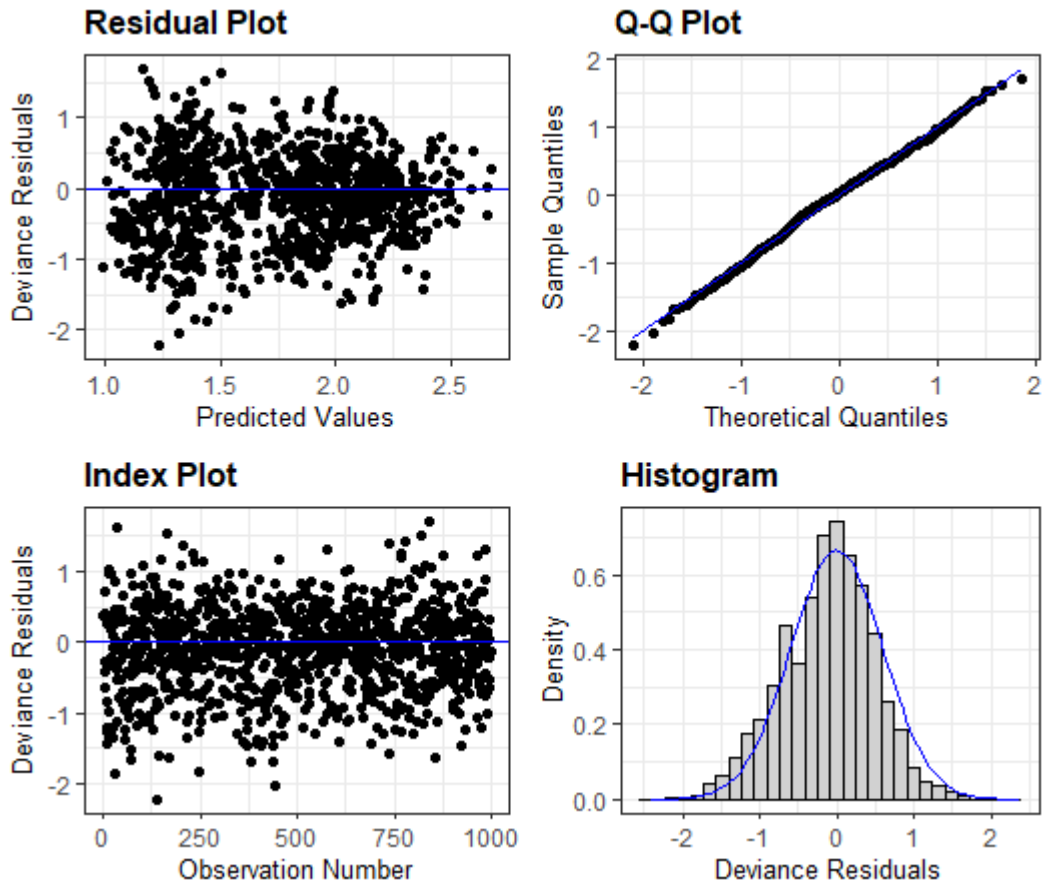

Figure 10. Panel of diagnostic residual plots for the GLM model that includes effects of breed, living environment and activity on inattention score.

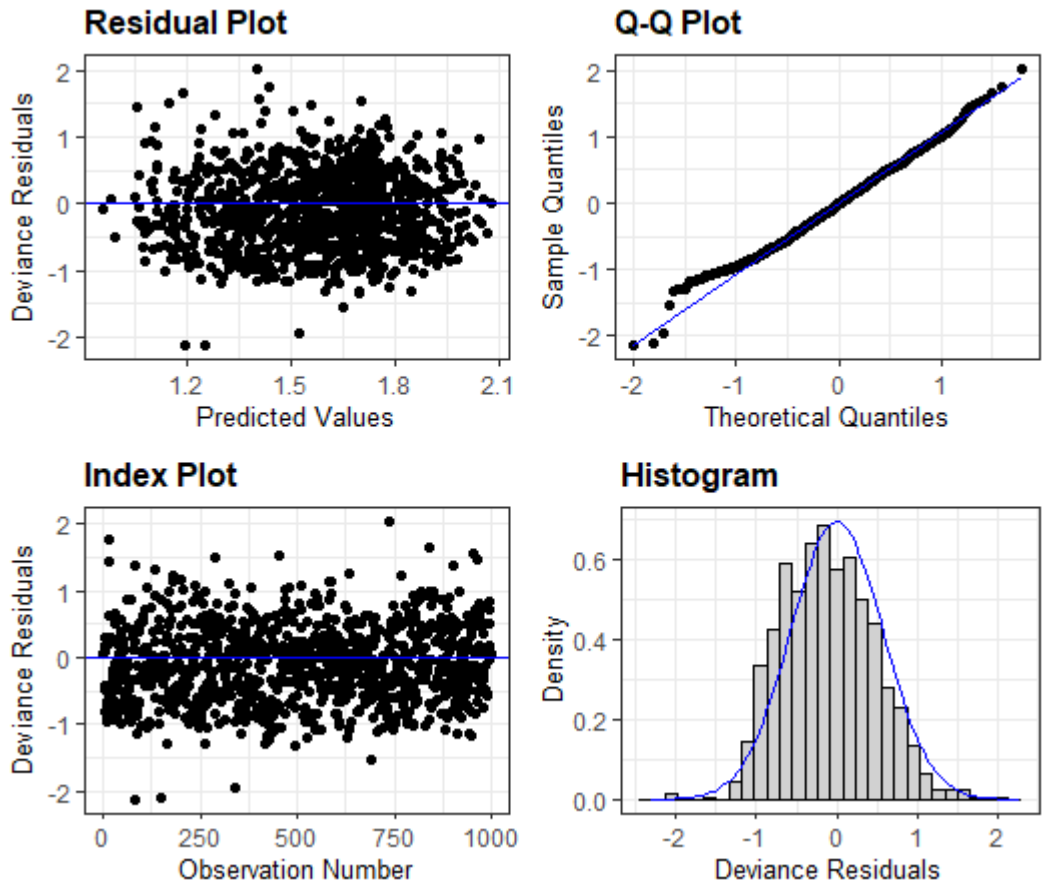

Figure 11. Panel of diagnostic residual plots for the GLM model that includes effects of breed group, living environment and activity to impulsivity score.

Appendix 3.1 Residual plots of breed differences on inattention score

Companion breed group

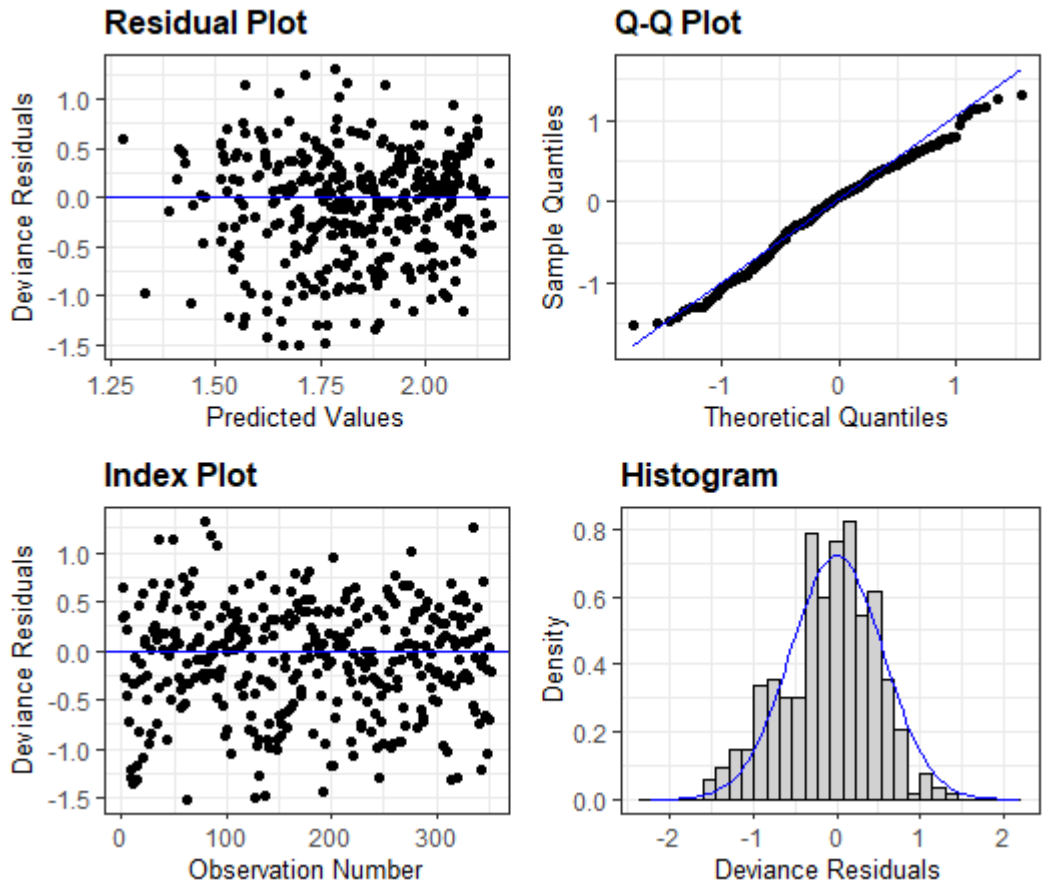

Figure 12. Panel of diagnostic residual plots for GLM model of companion breed group predicting inattention score.

Herding breed group

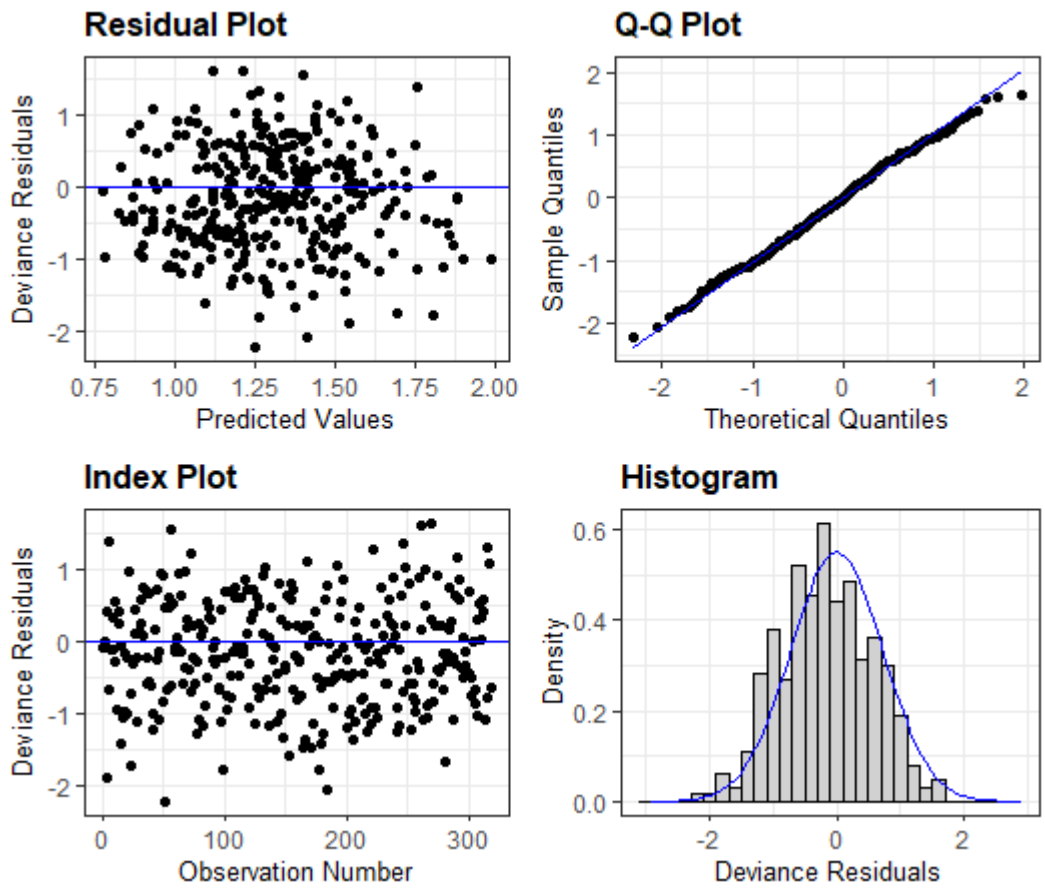

Figure 13. Panel of diagnostic residual plots for the GLM model of herding breed group predicting inattention score.

Primitive breed group

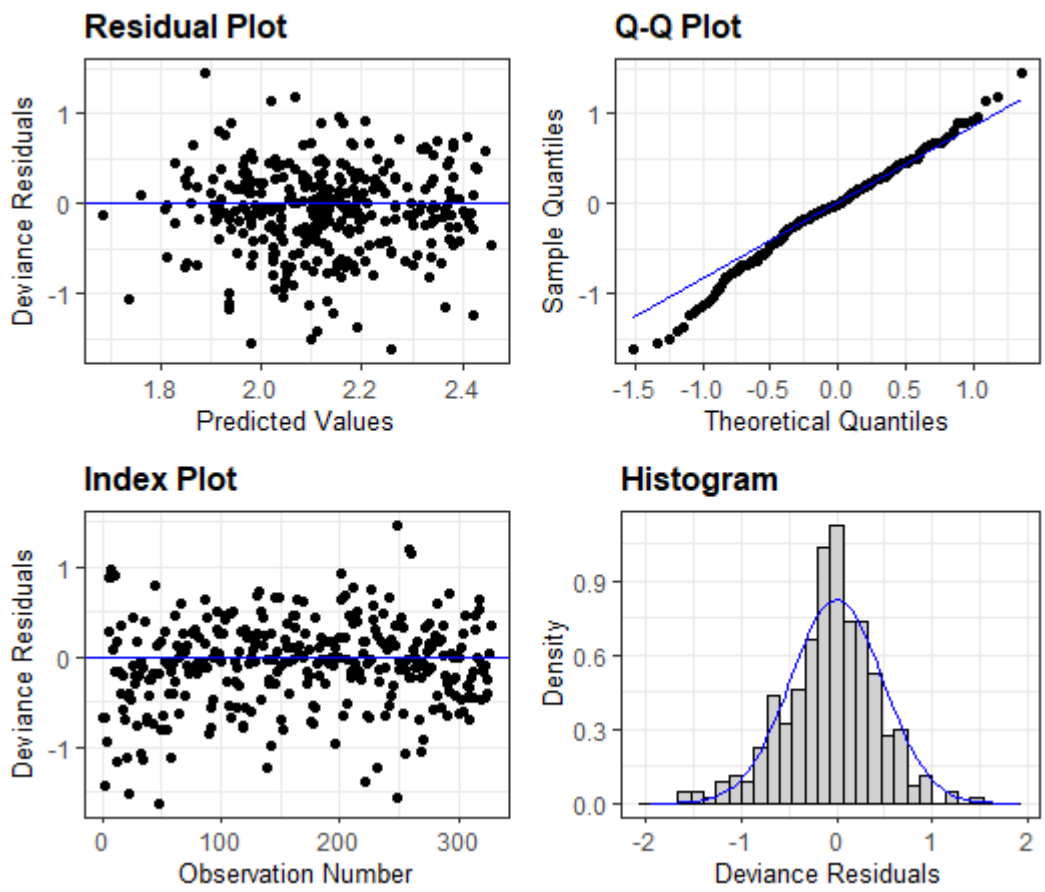

Figure 14. Panel of diagnostic residual plots for the GLM model of primitive breed group predicting inattention score.

Appendix 3.2 Residual plots of breed differences in impulsivity score

Companion breed group

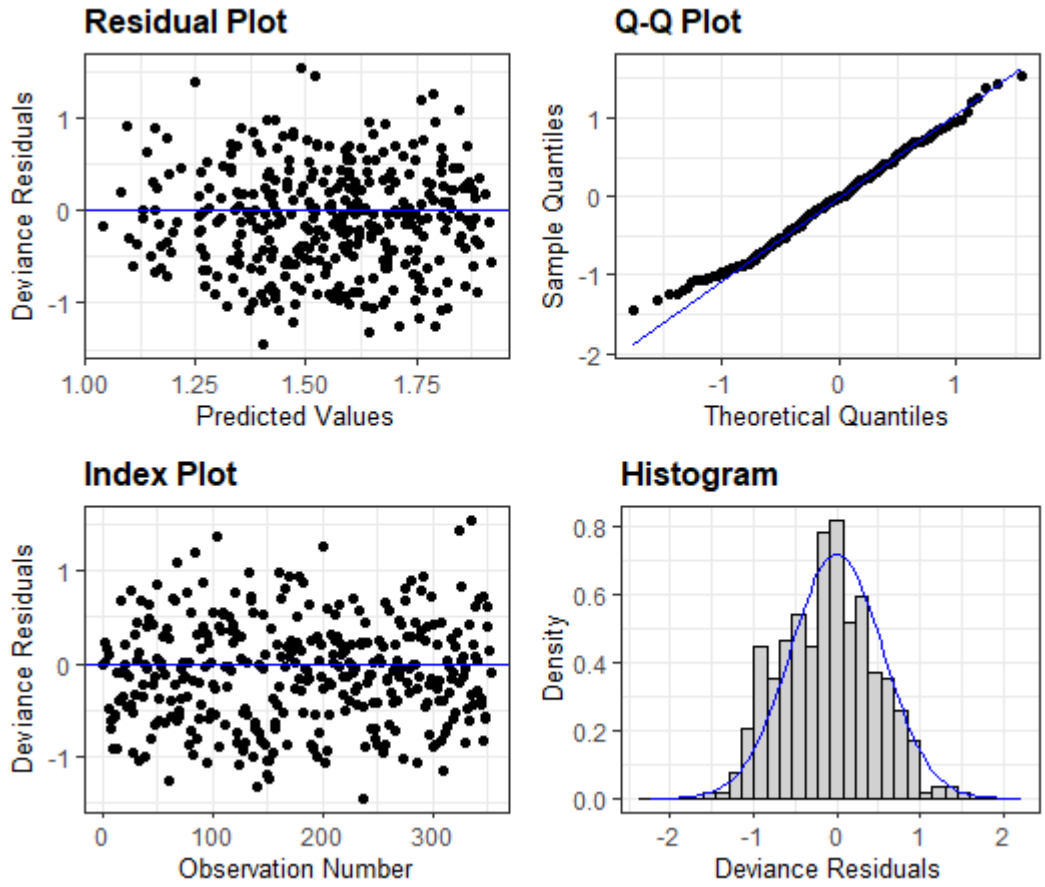

Figure 15. Panel of diagnostic residual plots for the GLM model of companion breed group predicting impulsivity score.

Herding breed group

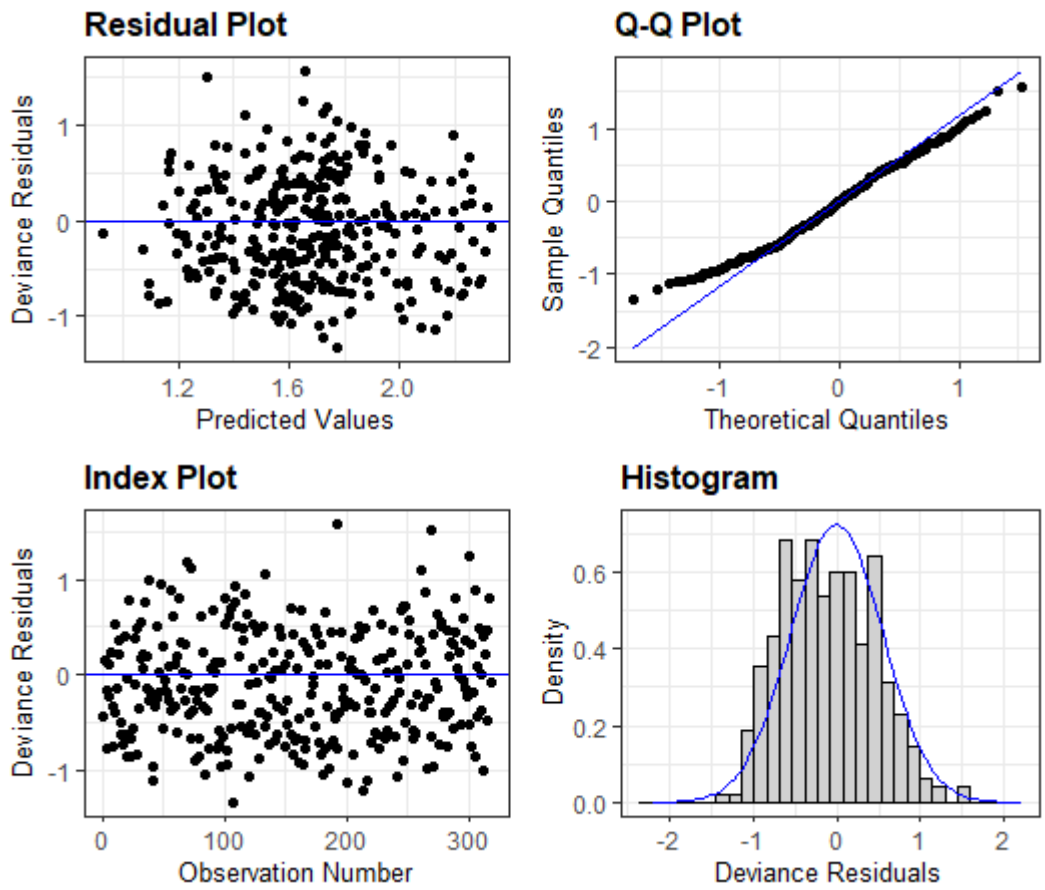

Figure 16. Panel of diagnostic plots for the GLM model of herding breed group predicting impulsivity score.

Primitive breed group

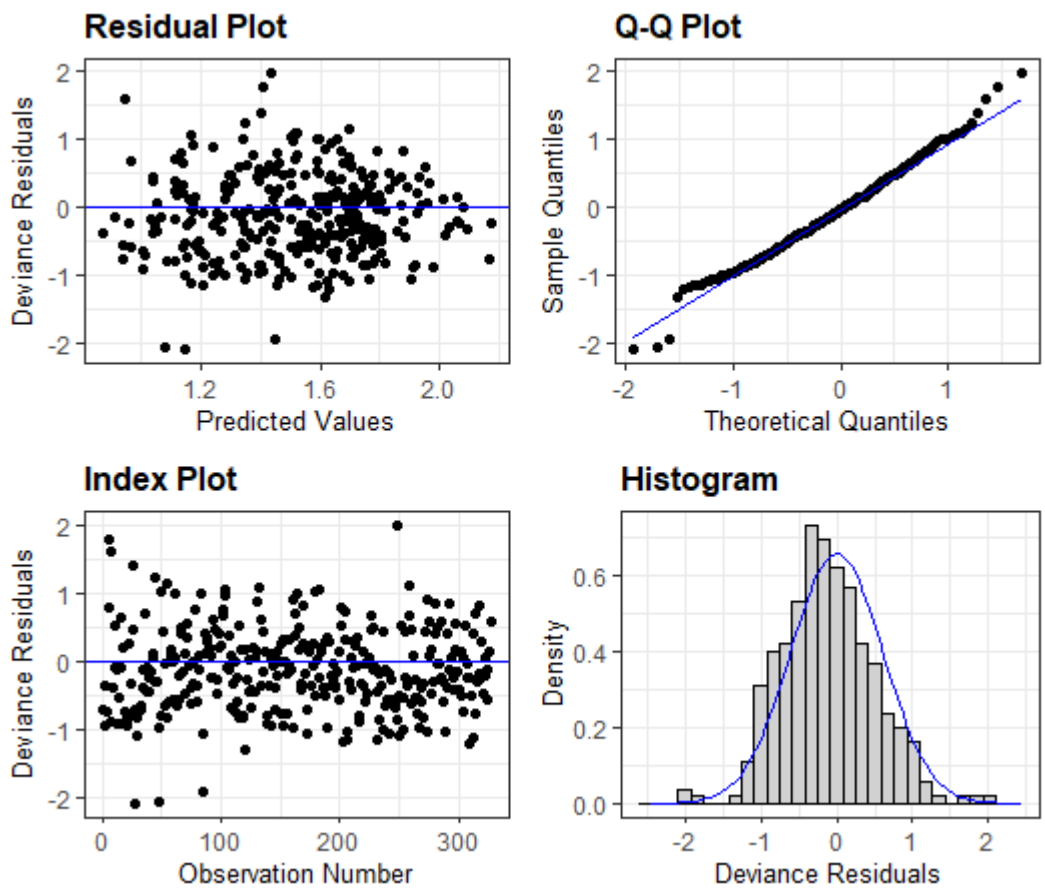

Figure 17. Panel of diagnostic residual plots for the GLM model of primitive breed group, predicting impulsivity score.

Appendix 4 Paired comparisons of variables for inattention

Table 15. Results of paired comparisons of variables with standard error (SE) as well as a degree of freedom (DF).

contrast	esti-mate	SE	DF	t ratio	p value
Companion breed - Herding breed	0.33	0.06	986	5.9	**<.0001**
Companion breed - Primitive breed	-0.15	0.05	986	-3.2	**0.004**
Herding breed - Primitive breed	-0.48	0.05	986	-9.3	**<.0001**
female – male	-0.06	0.04	986	-1.6	0.103
rural detached houses - urban apartment houses	-0.03	0.05	986	-0.5	0.957
rural detached houses - urban detached houses	0.06	0.05	986	1.1	0.669
rural detached houses - urban terraced houses	-0.08	0.05	986	-1.6	0.400
urban apartment houses - urban detached houses	0.09	0.05	986	1.7	0.334
urban apartment houses - urban terraced houses	-0.06	0.05	986	-1.1	0.694
urban detached houses - urban terraced houses	-0.14	0.05	986	-2.8	**0.031**
actively moving and engaging - (actively moving non-hobby)	0.06	0.06	986	0.9	0.818
actively moving and engaging - less active exercisers	0.02	0.06	986	0.3	0.987
actively moving and engaging - (less non-active exercisers)	-0.06	0.06	986	-0.9	0.787
(actively moving non-hobby) - less active exercisers	-0.04	0.06	986	-0.6	0.925
(actively moving non-hobby) - (less non-active exercisers)	-0.11	0.05	986	-2.1	0.146
fewer active exercisers - (less non-active exercisers)	-0.07	0.05	986	-1.4	0.515

Appendix 5 Paired comparisons of variables for impulsivity

Table 16. Results of paired comparisons of variables.

Contrast	Estimate	SE	DF	t ratio	P value
Companion breed - Herding breed	0.03	0.04	986	0.7	0.745
Companion breed - Primitive breed	-0.04	0.03	986	-1.2	0.426
Herding breed - Primitive breed	-0.06	0.03	986	-1.9	0.126
Female – male	0.00	0.04	986	0.0	0.986
rural detached houses - urban apartment houses	-0.02	0.06	986	-0.3	0.991
rural detached houses - urban detached houses	0.06	0.05	986	1.2	0.626
rural detached houses - urban terraced houses	-0.06	0.06	986	-1.1	0.665
urban apartment houses - urban detached houses	0.08	0.05	986	1.5	0.421
urban apartment houses - urban terraced houses	-0.05	0.05	986	-0.9	0.819
urban detached houses - urban terraced houses	-0.13	0.05	986	-2.4	0.081
actively moving and engaging - actively moving non-hobby	0.02	0.07	986	0.3	0.989
actively moving and engaging - less active exercisers	-0.02	0.06	986	-0.4	0.981
actively moving and engaging - less non-active exercisers	0.00	0.06	986	0.0	1.000
actively moving non-hobby - less active exercisers	-0.04	0.06	986	-0.7	0.901

actively moving non-hobby - less non-active exercisers	-0.02	0.05	986	-0.4	0.971
fewer active exercisers - less non-active exercisers	0.02	0.06	986	0.3	0.986

Appendix 6 Paired comparisons of variables for inattention by breed groups

Table 17. Results of paired comparisons of variables.

	Companion breed group				
contrast	esti-mate	SE	DF	t ratio	p value
female – male	-0.02	0.06	343	-0.4	0.666
rural detached houses - urban apartment houses	-0.08	0.09	343	-0.9	0.811
rural detached houses - urban detached houses	0.08	0.09	343	0.9	0.820
rural detached houses - urban terraced houses	-0.03	0.10	343	-0.3	0.987
urban apartment houses - urban detached houses	0.16	0.07	343	2.2	0.118
urban apartment houses - urban terraced houses	0.05	0.07	343	0.6	0.924
urban detached houses - urban terraced houses	-0.11	0.08	343	-1.4	0.493
actively moving and engaging - actively moving non-hobby	-0.17	0.15	343	-1.2	0.644
actively moving and engaging - less active exercisers	-0.26	0.15	343	-1.7	0.340
actively moving and engaging - less non-active exercisers	-0.26	0.14	343	-1.9	0.239
actively moving non-hobby - less active exercisers	-0.08	0.10	343	-0.8	0.838
actively moving non-hobby - less non-active exercisers	-0.09	0.07	343	-1.2	0.629
fewer active exercisers - less non-active exercisers	0.00	0.09	343	0.0	1.000
moves a lot – moves a little	-0.17	0.08	343	-2.0	**0.044**
	Herding breed group				
contrast	esti-mate	SE	DF	t ratio	p value

female – male	-0.16	0.08	309	-2.0	0.051
rural detached houses - urban apartment houses	0.11	0.12	309	1.0	0.774
rural detached houses - urban detached houses	0.12	0.11	309	1.1	0.677
rural detached houses - urban terraced houses	-0.13	0.11	309	-1.1	0.667
urban apartment houses - urban detached houses	0.01	0.12	309	0.1	1.000
urban apartment houses - urban terraced houses	-0.24	0.12	309	-2.0	0.193
urban detached houses - urban terraced houses	-0.25	0.12	309	-2.1	0.140
actively moving and engaging - actively moving non-hobby	0.08	0.16	309	0.5	0.966
actively moving and engaging - less active exercisers	0.03	0.09	309	0.3	0.988
actively moving and engaging - less non-active exercisers	-0.20	0.17	309	-1.2	0.645
actively moving non-hobby - less active exercisers	-0.05	0.16	309	-0.3	0.991
actively moving non-hobby - less non-active exercisers	-0.28	0.20	309	-1.4	0.532
fewer active exercisers - less non-active exercisers	-0.23	0.16	309	-1.4	0.494
moves a lot – moves a little	-0.12	0.11	309	-1.1	0.273

	Primitive breed group				
contrast	esti-mate	SE	DF	t ratio	p value
female – male	-0.02	0.05	318	-0.3	0.754
rural detached houses - urban apartment houses	-0.07	0.08	318	-0.9	0.827
rural detached houses - urban detached houses	-0.03	0.07	318	-0.4	0.976
rural detached houses - urban terraced houses	-0.08	0.08	318	-1.1	0.708
urban apartment houses - urban detached houses	0.04	0.08	318	0.5	0.956
urban apartment houses - urban terraced houses	-0.01	0.08	318	-0.2	0.998

urban detached houses - urban terraced houses	-0.05	0.07	318	-0.7	0.886
actively moving and engaging - actively moving non-hobby	0.11	0.08	318	1.4	0.510
actively moving and engaging - less active exercisers	0.09	0.09	318	0.9	0.801
actively moving and engaging - less non-active exercisers	0.01	0.08	318	0.2	0.999
actively moving non-hobby - less active exercisers	-0.03	0.09	318	-0.3	0.991
actively moving non-hobby - less non-active exercisers	-0.10	0.07	318	-1.5	0.441
fewer active exercisers - less non-active exercisers	-0.07	0.08	318	-0.9	0.784
moves a lot – moves a little	-0.01	0.06	318	-0.1	0.901

Appendix 7 Paired comparisons of variables for impulsivity by breed groups

Table 18. Results of paired comparisons of variables.

	Companion breed group				
contrast	estimate	SE	DF	t ratio	p value
female	-0.03	0.06	343	-0.5	0.606
rural detached houses - urban apartment houses	-0.12	0.10	343	-1.3	0.568
rural detached houses - urban detached houses	-0.02	0.10	343	-0.2	0.995
rural detached houses - urban terraced houses	-0.09	0.10	343	-0.9	0.822
urban apartment houses - urban detached houses	0.10	0.08	343	1.3	0.565
urban apartment houses - urban terraced houses	0.03	0.08	343	0.4	0.974
urban detached houses - urban terraced houses	-0.07	0.09	343	-0.8	0.871
actively moving and engaging - (actively moving non-hobby)	-0.16	0.16	343	-1.0	0.739
actively moving and engaging - less active exercisers	-0.19	0.17	343	-1.1	0.675
actively moving and engaging - (less non-active exercisers)	-0.18	0.15	343	-1.2	0.602
(actively moving non-hobby) - less active exercisers	-0.02	0.11	343	-0.2	0.996
(actively moving non-hobby) - (less non-active exercisers)	-0.02	0.08	343	-0.3	0.992
fewer active exercisers - (less non-active exercisers)	0.00	0.09	343	0.0	1.000
	Herding breed group				

contrast	estimate	SE	DF	t ratio	p value
female	0.01	0.06	309	0.1	0.897
rural detached houses - urban apartment houses	0.01	0.10	309	0.1	1.000
rural detached houses - urban detached houses	0.01	0.09	309	0.1	1.000
rural detached houses - urban terraced houses	-0.20	0.09	309	-2.3	0.109
urban apartment houses - urban detached houses	0.00	0.10	309	0.0	1.000
urban apartment houses - urban terraced houses	-0.21	0.10	309	-2.2	0.135
urban detached houses - urban terraced houses	-0.21	0.09	309	-2.2	0.116
actively moving and engaging - (actively moving non-hobby)	0.02	0.13	309	0.2	0.999
actively moving and engaging - less active exercisers	0.04	0.07	309	0.5	0.962
actively moving and engaging - (less non-active exercisers)	-0.09	0.14	309	-0.7	0.903
(actively moving non-hobby) - less active exercisers	0.02	0.13	309	0.1	0.999
(actively moving non-hobby) - (less non-active exercisers)	-0.12	0.17	309	-0.7	0.899
fewer active exercisers - (less non-active exercisers)	-0.13	0.13	309	-1.0	0.756

Primitive breed group

contrast	estimate	SE	DF	t ratio	p value
female	0.04	0.07	318	0.5	0.621
rural detached houses - urban apartment houses	0.06	0.11	318	0.6	0.935

rural detached houses - urban detached houses	0.16	0.10	318	1.6	0.369
rural detached houses - urban terraced houses	0.07	0.11	318	0.6	0.924
urban apartment houses - urban detached houses	0.09	0.10	318	0.9	0.813
urban apartment houses - urban terraced houses	0.00	0.11	318	0.0	1.000
urban detached houses - urban terraced houses	-0.09	0.10	318	-0.9	0.812
actively moving and engaging - (actively moving non-hobby)	0.05	0.11	318	0.4	0.974
actively moving and engaging - less active exercisers	-0.10	0.13	318	-0.8	0.853
actively moving and engaging - (less non-active exercisers)	0.02	0.10	318	0.2	0.995
(actively moving non-hobby) - less active exercisers	-0.15	0.12	318	-1.3	0.587
(actively moving non-hobby) - (less non-active exercisers)	-0.02	0.09	318	-0.3	0.994
fewer active exercisers - (less non-active exercisers)	0.13	0.11	318	1.2	0.635

Appendix 8 Power analysis for statistical models

Table 19. Power analysis of t-test for inattention score.

Group	Cohen's d	Power	Required sample size	N
Companion breed x herding breed	-0.400	0.8	99	670
Companion breed x primitive breed	-0.138	0.8	826	670
Herding breed x primitive breed	0.249	0.8	253	670

Table 20. Power analysis of t-test for impulsivity score.

Group	Cohen's d	Power	Required sample size	N
Companion breed x herding breed	0.080	0.8	2456	670
Companion breed x primitive breed	0.016	0.8	58111	670
Herding breed x primitive breed	-0.062	0.8	4102	670

Tabel 21. Power analysis for generalized linear models. f^2 refers to Cohen's effect size measure, v stands for estimated sample size and N stands for total sample size.

Data	f^2	v	N	Power
All breeds	0.159	80	997	1.00
Companion breed group	0.039	306	352	0.85
Herding breed group	0.069	173	318	0.98
Primitive breed group	0.024	497	327	0.59