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The long term effect of stress on the cognition of rescued dogs (*Canis familiaris*).

John O'Riordan

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Contents:

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1. Abstract

Dogs that have been rescued, relocated, or have lived in animal shelters could suffer from high levels of stress. The effect that this can have on their behaviour and cognition long-term has not been thoroughly studied. This study investigates possible underlying cognitive impairment that may lead to differences in behaviour between rescue dogs and "normal" dogs using a series of cognitive tests. These tests are simple enough that they can be performed by owners in their own homes, therefore, citizen science was used to collect behavioural data on rescue dogs (n = 30) and "normal" control dogs (n = 20). Owners of the dogs were also required to complete both an MDORS and DPQ questionnaire to assess the dog/owner relationship and personality of the dog, respectively. Rescue dogs show some signs of cognitive impairment compared with non-rescued dogs, particularly in their ability to maintain eye contact with their owner, performing significantly worse than control dogs in an eye contact test. However, they performed significantly better than control dogs in a simple memory test. The results of the study show that there are some cognitive differences between rescue dogs and "normal" dogs and that citizen science may be a viable method to collect behavioural data on rescue dogs after they are rehomed.

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2. Introduction

Dogs (*Canis familiaris*) were the first animals to be domesticated ~~by~~ ~~humans r~~oughly 15,000 years ago (Larson et al., 2012~~Jensen, 2007~~). They have since been used for a wide range of activities including hunting, herding, sports, assistance for disabled people, and detection of drugs and explosives. However, the majority of dogs are kept ~~simply~~ primarily for companionship ~~(Jensen, 2015),~~ with the expectation that the relationship will be emotionally fulfilling (Marston and Bennett, 2003). While the numbers vary considerably between countries, in the UK it is estimated that 10% of all companion dogs are relinquished to dog shelters (Jensen, 2007), with at least 30% being for behavioural reasons – dogs with perceived behavioural problems are significantly more likely to be returned than other dogs (Wells, 1996, Disel et al., 2008). Ownership of rescued dogs is becoming increasingly common – in 2016 there were a total of 77 million dogs in US households, 28% of which were rescued from animal shelters (Kazi, 2019).

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Dogs that have been rescued and adopted from animal shelters are more likely to display behavioural problems than those acquired as puppies from various sources including breeders,

friends, or relatives (Jagoe, 1994, Gates et al., 2018). Behavioural problems reported in rescue dogs include fearfulness, aggression, separation anxiety, destructiveness, and excessive activity (Wells and Hepper, 2000). While the severity of the problems varies greatly – and what may be interpreted as a "problem behaviour" varies depending on owner personality and experience – behavioural problems are one of the major reasons for dogs being relinquished; particularly for rescue dogs returned to shelters after having been adopted (Wells and Hepper, 2000).

It has been shown that dogs that have been rescued, relocated, or have lived in animal shelters for any period of time can suffer from both acute and long-term stress (Rooney et al., 2007, Beerda et al., 1997). The specific effect that this could have on their behaviour and cognition in the long term has not been thoroughly investigated and is therefore not well understood. Hence, it is important to try and understand the possible underlying cognitive mechanisms that may lead to differences in behaviour between rescue dogs and "normal" dogs.

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Neural pathways in the prefrontal cortex can be considerably impaired by neurochemical changes that occur during both acute and chronic stress (Arnsten, 2009). The prefrontal cortex is the area of the brain that controls complex cognitive processes called executive functions (including working memory, reasoning, and decision making) (Alvarez and Emory, 2006, Olsen, 2018). Exposure to even mild acute stress can severely impair executive function, while large-scale structural changes can occur in the prefrontal cortex when an individual is exposed to chronic stress (Arnsten, 2009).

Recently, Horschler et al., (2019) and Watowich et al., (2020) used a series of cognitive tests that assess multiple aspects of executive function in dogs. These tests are designed to be simple enough that they can be performed by dog owners in their own homes for use in citizen science projects (Stewart et al., 2015). These tests (conducted through websites such as *Dognition.com*) in which owners perform simple behavioural tests with their dogs, have provided reliable data used in large-scale dog studies (Stewart et al., 2015, Watowich et al., 2020). Citizen science has become increasingly popular in recent years; ubiquitous high-speed internet has allowed for data to be collected by large numbers of non-scientists and easily sent to researchers. This has led to the availability of much larger data sets for studies that would have limited sample sizes using traditional methods (Stewart et al., 2015), such as requiring dog owners to bring their dogs to a standardized test room at a particular location. This has the potential to be a particularly effective method to recruit rescue dogs as many may have behavioural issues that

prevent them from traveling in cars (Gandia Estelles and Mills 2006), or may be fearful, anxious or stressed in novel environments (Landsberg et al., 2013), or in the presence of unfamiliar individuals such as the experimenter (Pullen et al., 2012). Most behavioural studies on relocated dogs are carried out in dog shelters and kennels (Breeda et al., 1997, Rooney, 2007, Pullen et al., 2012) – very few studies are conducted on dogs after they are rehomed; most that have been done are in the form of owner-completed questionnaires (such as Wells and Hepper, 2000, Marder et al., 2013) rather than direct behavioural tests. Hence, citizen science may be an effective way to carry out experimental behavioural research on rescue dogs after they have been rehomed – without having to subject possibly traumatized dogs to unfamiliar and potentially stressful experimental conditions.

The quality of the relationship a dog has with its owner may influence its behaviour and emotional state. Topal et al., (1997) showed that problem solving behaviour in dogs is significantly affected by their relationship with their owner – therefore it is important to assess the quality of the dog-owner relationship using an empirically validated survey as this may affect the outcome of behavioural tests. The Monash Dog Owner Relationship Scale (MDORS) developed by Dwyer et al. (2006) is a validated and widely used relationship scale that assesses both the perceived benefits and costs of the dog-human relationship.

Behaviour can also be influenced by personality (Barnard et al., 2018). Personality is difficult to define but it can generally be determined by assessing behavioural traits that are stable over time and in similar situations (Jensen, 2007). Personality could have a considerable impact on the behaviour of dogs, influencing their decision-making processes and emotional states, and reactions to novel stimuli, and therefore, how they may respond to behavioural tests (Barnard et al., 2018). Hence, when investigating behaviour, it could be valuable to also assess the personality of the dogs being tested by using an empirically validated survey such as the Dog Personality Questionnaire (DPQ) which has been used in a wide range of dog behavioural studies (Jones, 2008, Posluns et al., 2017).

2.1 Aims of the Study

The primary aim of this study was to determine if relocated dogs showed signs of impaired cognitive function compared with non-relocated dogs, which could indicate long-term impacts of past stress on cognition. In order to test this, owners of dogs that have been rescued

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either from dog shelters, imported from abroad, or from other sources were asked to perform a series of simple cognitive tests with their dogs at home. The control group was comprised of owners who had raised their dogs since they were 6 months old or younger and were asked to perform the same tests. Relocated dogs were expected to perform more poorly in the cognitive tests than the control dogs and display more stress behaviours while performing the tests.

In addition, I wanted to determine how the dogs performance in the cognitive tests may be correlated with both the dog's personality and the dog's relationship with its owner. Owners were asked to complete both a Dog Personality Questionnaire (Jones, 2008) and the Monash Dog Owner Relationship Scale (Dwyer et al., 2006) to assess their perception of their dog's personality and their relationship with their dog, respectively.

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3. Materials and Methods

3.1 Subjects

Dog owners were recruited online via open calls on social media (N = 47; 44 females, 3 males). Forty four of the dog owners were Swedish, one was Irish, and two were of unknown nationalities. Three of owners had two dogs and therefore the total number of dogs in study was 50 (29 males, . Relocated dogs (N = 30; 16 males, 14 females; mean age = 5.6 +/- 0.51) were recruited from September to December 2020. Non-relocated dogs (control dogs; N = 20; 13 males, 6 females; mean age = 5.8 +/- 0.75) were recruited for the control group with a separate open call during October-December 2020 (Table 1). The owners were provided with a link to a Microsoft Sway page containing both written and video instructions for how to carry out the cognitive tests, in addition to information on how to upload the videos (see Appendix). Dog owners were asked to record themselves performing four cognitive tests with their dogs at home. These videos were then uploaded to a Microsoft One Drive folder where they could be accessed for behavioural analysis.

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Table 1: Dogs in the study.

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Group	Dog	Breed	Sex	Age
Rescue	Polly	Tibetan terrier	Female	9
Rescue	Peteca	Mixed	Female	3
Rescue	Daisy	Mixed	Female	3
Rescue	Elvis	Mixed	Male	4

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Rescue	Texas	Danish-Swedish farm dog	Male	9	
Rescue	Tessie	Shetland Sheepdog	Female	8	
Rescue	Lily	Staffordshire bullterrier	Female	7	
Rescue	Trini	Mixed	Female	3	
Rescue	Fanny	Schapendoes	Female	4	
Rescue	Milou	Barbet	Male	9	
Rescue	Frost	Spanish water dog	Male	5	
Rescue	Tyra	Mixed	Female	9	
Rescue	Bosse	American Staffordshire terrier	Male	6	
Rescue	Idun	Hovawart	Female	6	
Rescue	Maja	Irish soft coated wheaten terrier	Female	6	
Rescue	Allan	Mixed	Male	2	
Rescue	Milton	Portuguese water dog	Male	8	
Rescue	Ella	Portuguese water dog	Female	2	
Rescue	Loke	Basenji	Male	3	
Rescue	Dante	Mixed	Male	11	
Rescue	Izzy	Parson Russell terrier	Female	9	
Rescue	Bobby	Mixed	Male	1	
Rescue	Ghost	Mixed	Male	4	
Rescue	Buster	Mixed	Male	10	
Rescue	Rexi	Mixed	Male	2	
Rescue	Pippi	Bordercollie	Female	6	
Rescue	Nero	Mixed	Male	5	
Rescue	Onix	German Shepherd	Male	4	
Rescue	Shmi	Mixed	Female	3	
Rescue	Molle	Beagle	Male	5	
Control	Shiki	Kooikerhondje	Female	3	
Control	Maja	Pumi	Female	8	
Control	Elda	Pumi	Female	4	
Control	Calla	Labrador	Female	6	
Control	Vilde	Labrador	Female	3	
Control	Moril	Berger Picard	Male	8	
Control	Lucy	Mixed	Female	4	
Control	Rufus	White shepherd dog	Male	4	

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Control	Tooticki	Mixed	Female	1
Control	Aston	Mixed	Male	4
Control	Pixie	Mixed	Female	10
Control	Daisy	Mixed	Female	8
Control	Virus	Mixed	Female	13
Control	Juni	Havanese bichon	Female	3
Control	Samson	Scotch Collie	Male	6
Control	Chaska	Mixed	Female	7
Control	Eddie	Standard Schnauzer	Male	1
Control	Zima	Mixed	Female	3
Control	Robban	Belgian Malinois	Male	10
Control	Lily	Mixed	Female	10

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3.2 Cognitive Tests

The first three cognitive tests were adapted from previous citizen science studies which tested several aspects of executive function in dogs (Stewart et al., 2015, Watowich et al., 2020). The fourth test was based on a memory test used by Iotchev et al., (2020). The owners were instructed to perform each cognitive test twice. In addition, each test had a simplified "warm-up" version that was performed twice prior to the actual test; this was to teach both the dog and the owner what was expected of them during the test. The following is a brief description of each test performed by the owners (for the full list of step-by-step instructions received by the owners, see Appendix).

1. **Eye Contact**: The owner stands facing their dog roughly 1 m in front of them. The owner then holds a treat to their face and maintains eye contact with their dog for 90 seconds or until the dog breaks eye contact for more than 3 seconds.
    - **Warm up**: The same as the test but eye contact was held for 10 s seconds instead of 90 seconds.
2. **Inferential Reasoning**: The owner places 2 cups on the ground 2 m apart. The owner stands or sits between the cups facing their dog 2 m in front of the cups (Figure. 1). The dog can be instructed to stay or held in place by a helper. Allowing the dog to see, the owner places a treat under one cup and pretends to place a treat under the other cup.

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The owner then raises the empty cup, showing the dog that it is empty, before placing it back on the ground. The dog is then released and allowed to approach the cups.

- **Warm up:** The same as the test except *both* cups were raised instead of just the empty cup.

3. **Memory Test A**: The owner places 2 cups on the ground 2m apart. The owner stands or sits between the cups facing their dog 2m in front of the cups (Figure. 1). The dog can be instructed to stay or held in place by a helper. Allowing the dog to see, the owner places a treat under one cup. The dog must continue to stay or be held by the helper for a period of 60s. After 60s the dog is released and allowed to approach the cups.
    - **Warm up:** The same as the test except the dog was released immediately instead of after 60s.
4. **Memory Test B**: The owner places five cups on the ground in a semi-circle with each cup spaced 1m apart. The dog is instructed to stay or held by a helper 1.5m in front of the semi-circle of cups (Figure 2). Allowing the dog to see, the owner places a treat under one of the five cups. The dog is then removed from the room for a period of 60 s. After 60s the dog is brought back into the room and immediately released to approach the cups.
    - **Warm up:** The same as the test except the dog was removed from the room for 5s instead of 60s.

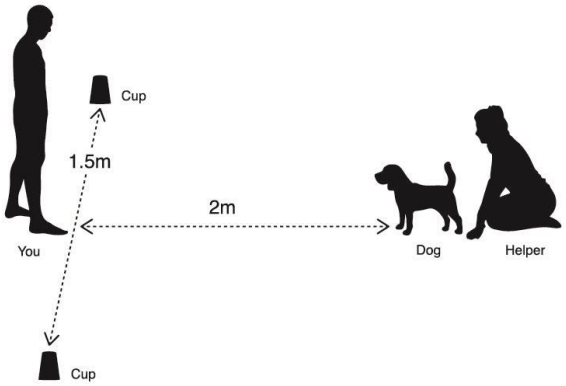

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Figure 1: The experimental set-up for the inferential reasoning test and memory test A. This is the diagram that the owners were provided in the instructions.

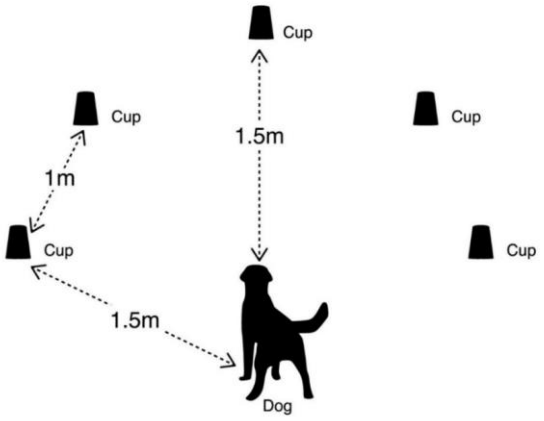

Figure 2: The experimental set-up for memory test B. This is the diagram that the owners were provided in the instructions.

3.3 Video Analysis

The videos of the tests were downloaded from Microsoft OneDrive and scored according to the ethogram in Table 2. Some owners only performed each test once, therefore the first video the owners uploaded was used for each test where the owner uploaded two videos (unless the owner made an obvious error in the set up or execution of a test, in which case the second video was used). A second observer scored 10% of the videos to establish inter-observer reliability.

Table 2: Ethogram of dog behaviours recorded in the videos of the cognitive tests, including stress-related behaviours.

Test	Behaviour	Type	Description
Eye Contact	Eye contact	Duration	Face directed towards owner's face.
	Break contact	Latency and Frequency	Face is not directed towards the owner's face for less than 3 seconds.
Reasoning	Looks at empty cup	Yes/No, Duration	Face is directed towards the empty cup when the owner lifts it.

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	Select treat	Yes/No, Latency to choose	Moves to within a head-length of the cup with the treat.
Memory A	Looks at cup with treat	Yes/No, Duration	Face is directed towards the cup under which a treat is being placed.
	Select treat	Yes/No, Latency to choose	Moves to within a head-length of the cup with the treat.
Memory B	Looks at cup with treat	Yes/No, Duration	Face is directed towards the cup under which a treat is being placed.
	Select treat	Yes/No, Latency to choose	Moves to within a head-length of the cup with the treat.
	Select empty cup	Frequency	Moves within a head-length of an empty cup.
All	~~Eye contact~~	~~Duration~~	~~Face directed towards owner's face.~~
Stress-related behaviours	Paw lift	Duration	Lifts one front paw off the ground and holds it curled near its chest.
	Snout lick	Duration	Extends tongue out of its mouth and licks its nose or other area on the snout.
	Yawn	Duration	Opens its mouth widely and closes its eyes.
	Panting	Duration	Tongue is extended out of its mouth, the dog's chest is moving rapidly and repetitively, and breathing is visible and/or audible.
	Turning away	Duration	Body is oriented 90o or more away from the owner.
	Cowering	Duration	Body posture is in a lowered or flat position with the head near the floor.
	Ears back	Duration	Ears flattened or folded against the side or back of the head.
	Tail down/tucked	Duration	The base of the tail is held lower than a 45 degree angle or curled between the hind legs.
	Whining	Duration	High-pitched vocalization.

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3.45 Surveys

The owners were required to complete~~fill out~~ two surveys: the Dog Personality Questionnaire (DPQ) to assess the personality of the dogs (Jones, 2008) and the Monash Dog Owner

Relationship Scale (MDORS) to assess the relationship between the owners and their dogs (Dwyer et al., 2006). The DPQ consists of 75 statements with responses ranked on a scale of 1 to 7 in order of agreement, with 1 being "Disagree Strongly" and 7 being "Agree Strongly". These 75 statements are grouped into five Factors: Fearfulness, Aggression Towards People, Activity/Excitability, Responsiveness to Training, and Aggression Towards Animals. Each question represents a "Facet" of its respective Factor (Jones, 2008). The MDORS contains 28 questions divided into three sub-scales: Dog-Owner Interaction, Perceived Emotional Closeness, and Perceived Costs (Dwyer et al. 2006). Links to online versions of the surveys were included in the Microsoft Sway page containing the instructions for the cognitive tests (see Appendix).

3.5 Data Analysis

Data were analysed using IBM SPSS Statistics 26. Non-parametric tests were used as the data were not normally distributed (see Appendix).

A Mann-Whitney U test was carried out to determine if there was a significant difference in the average duration of eye contact between the rescue and control groups. For both the Inferential Reasoning test and Memory Test A, chi-squared tests were used to determine if there was a significant difference between rescue and control groups in the proportion of correct choices. The Mann-Whitney U test was again used to determine if there was a significant difference between the rescue and control groups in the number of attempts required to choose the correct cup in Memory Test B in addition to a chi-squared test to determine if there was a difference in the proportion of dogs that required one attempt or more than one attempt to choose the correct cup between groups.

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Mann-Whitney U tests were used to determine if there was any difference between rescue and non-rescue dogs in percentage time spent displaying stress behaviours during each test. Spearman correlations were used to determine if there was any relationship between stress behaviours, performance in the Eye Contact test and Memory Test B, the subscales of the MDORS, and the factors and facets of the DPQ.

4. Results

4.1 Cognitive Tests

4.1.1 Eye Contact

Rescue dogs (n = 29) maintained eye contact for a significantly shorter period of time than control dogs (n = 19) (U = 162.5, SE +/- 45.082, p = 0.029) (Figure 3a). Rescue dogs had a tendency to spend more time displaying stress behaviours than control dogs during the Eye Contact test, however, the difference was not statistically significant (U = 347.5, SE +/- 45.648, p = 0.058) (Figure 3b).

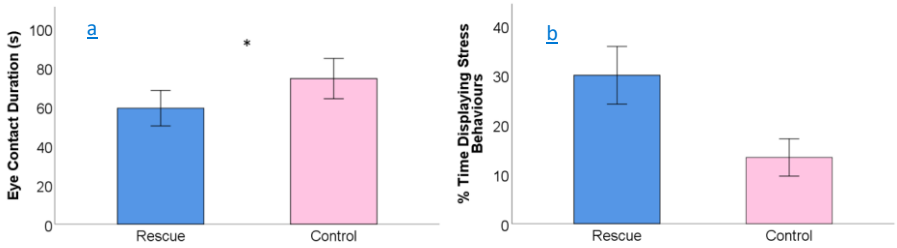

Figure 3: Eye Contact Test. Mean a) duration of eye contact (s +/-SE), and b) percentage of displayed stress related behaviour for rescue dogs (blue) and control dogs (pink). Error bars +/- SE, *p<0.05.

Stress behaviour of rescue dogs was significantly positively correlated with the factor Responsiveness to Training in the DPQ (r_s = 0.455, p = 0.029), its corresponding facet Controllability (r_s = 0.425, p = 0.043), and the facet Companionability (r_s = 0.425, p = 0.043). For control dogs, duration of eye contact was significantly positively correlated with the facet Companionability (r_s = 0.802, p = 0.009).

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4.1.2 Inferential Reasoning Test

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There was no significant difference between the proportion of rescue dogs (n = 28) and the proportion of control dogs (n = 19) that chose the correct cup in the Inferential Reasoning test (X^2(1, N = 47) = 0.923, p = 0.337) (Figure 4a). In addition, rescue ($\bar{x}$ = 21.225 +/-6.229 SE) and control ($\bar{x}$ = 8.263 +/- 2.937 SE) dogs did not differ in the percentage time spent displaying stress behaviours (U = 303, SE +/- 43.336, p = 0.393) (Figure 4b).

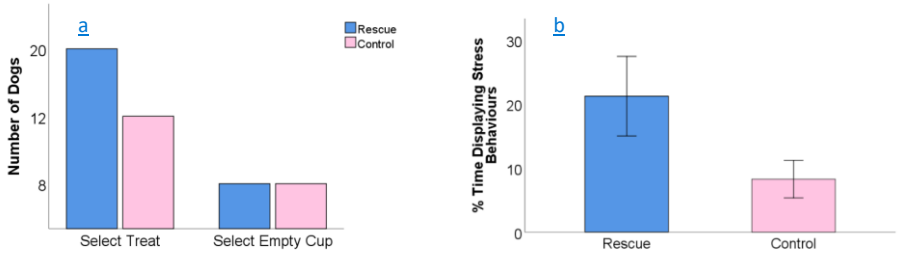

Figure 4: Inferential Reasoning Test. a) Number of dogs that chose the correct cup and incorrect cup in the inferential reasoning test and b) percentage of displayed stress related behaviour for rescue dogs (blue) and control dogs (pink). Error bars +/-SE.

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The percentage time rescue dogs spent displaying stress behaviours during the inferential reasoning test was significantly negatively correlated with the factor Activity/Excitability (r_s = - 0.432, p = 0.04) in the DPQ, and its corresponding facets Playfulness (r_s = - 0.455, p = 0.029) and Active Engagement (r_s = - 0.497, p = 0.016). It was also negatively correlated with the factor Aggression Towards Animals (r_s = - 0.426, p = 0.042) and positively correlated with stress levels during Memory Test B (r_s = 0.632, p = 0.001).

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factor Aggression Towards Animals (r_s = - 0.426, p = 0.042) and positively correlated with stress levels during Memory Test B (r_s = 0.632, p = 0.001).

Stress behaviour for control dogs was negatively correlated with the factor Companionability (r_s = -0.748, p = 0.02) while being positively correlated with Aggression Towards Dogs (r_s = 0.845, p = 0.004) and stress behaviour during Memory Test B (r_s = 0.705, p = 0.034).

4.1.3 Memory Test A

Rescue dogs (n = 25) were more likely than control dogs (n = 15) to remember where the treat was in Memory Test A (X^2(1, N = 40) = 4.404, p = 0.036) (Figure 5a). Stress behaviour did not differ between rescue ($\bar{x}$ = 22.792 +/-6.208 SE) and control ($\bar{x}$ = 12.233 +/-6.143 SE) dogs (U = 206, SE +/- 45.299, p = 0.619) (Figure 5b).

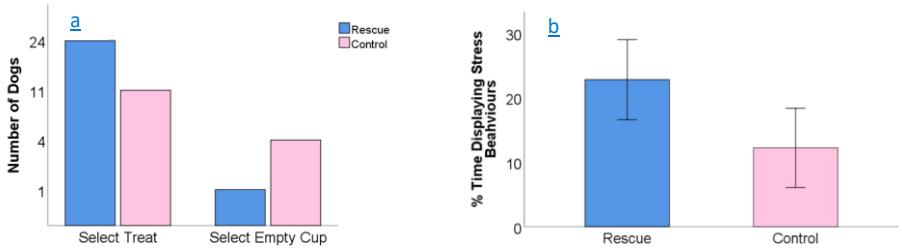

Figure 5: Memory Test A. a) Number of dogs that chose the correct cup and incorrect cup in Memory Test A and b) percentage of displayed stress related behaviour for rescue dogs (blue) and control dogs (pink). Error bars +/-SE.

For rescue dogs the percentage time spent displaying stress behaviours during Memory Test A was significantly positively correlated with stress behaviours during the Inferential Reasoning test (r_s = 0.593, p = 0.003) and Memory Test B (r_s = 0.691, p < 0.001). Stress behaviour during Memory Test A was also significantly negatively correlated with duration of eye contact (r_s = -0.486, p = 0.019). In addition, stress behaviour was negatively correlated with the personality traits Aggression Towards Animals (r_s = -0.538, p = 0.008) and its facet Prey Drive (r_s = -0.484, p = 0.019).

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For the control dogs, there was a negative correlation between the amount of time they spent displaying stress behaviours during Memory Test A and eye contact duration (r_s = -0.843, p = 0.004).

4.1.4 Memory Test B

There was no significant difference between rescue dogs (n = 25) and control dogs (n = 10) in the number of tries to find the correct cup ($\bar{x}$ = 2.36 +/-0.321 SE and $\bar{x}$ = 2.3 +/-0.559 SE respectively) in Memory Test B (U = 128.5, SE +/- 25.649, p = 0.9) or in the proportion of dogs that chose the correct cup on the first try (X^2(1, N = 36) = 0.024, p = 0.877) (Figure 6a). There was no difference between rescue ($\bar{x}$ = 30.658 +/-7.29 SE) and control ($\bar{x}$ = 19.950 +/-6.656 SE) dogs in the percentage time spent displaying stress behaviours (U = 147, SE +/-28.179, p = 0.566) (Figure 6b).

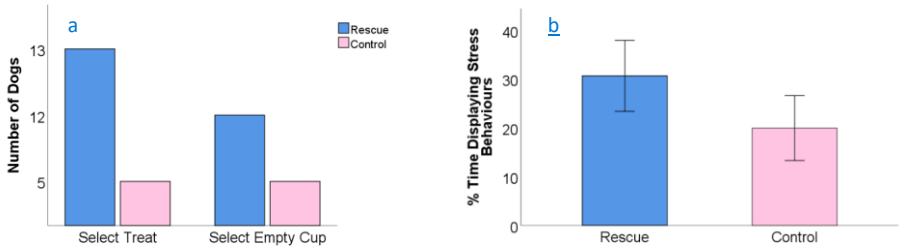

Figure 6: Memory Test B. a) Number of dogs that chose the correct cup and incorrect cup in Memory Test B and b) percentage of displayed stress related behaviour for rescue dogs (blue) and control dogs (pink). Error bars +/-SE.

For rescue dogs the number of tries to find the correct cup during Memory Test B was significantly negatively correlated with the number of days the dog had attended a training session in the last 2 years (r_s = - 0.490 , p = 0.018), and significantly negatively correlated with the MDORS sub-scale Perceived Costs (r_s = -0.456, p = 0.029). In addition, there was a negative correlation between stress behaviours during Memory Test B and duration of eye contact during the Eye Contact test (r_s = - 0.589, p = 0.003).

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The number of tries to find the correct cup was positively correlated with age for control dogs (r_s = 0.757, p = 0.018) and negatively correlated with the personality traits Aggression Towards Animals (r_s = -0.712, p = 0.032) and Dominance Over Other Dogs (r_s = -0.744, p = 0.022). It was also negatively correlated with stress behaviours during the Eye Contact test (r_s = -0.679, p = 0.044). Stress behaviour during the test was negatively correlated with Companionability (r_s = -0.675, p = 0.046) and Prey Drive (r_s = -0.681, p = 0.043), while being positively correlated with Controllability (r_s = 0.693, p = 0.039).

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4.1.5 Age and Sex Comparisons

There were no statistically significant differences found in the performance in the tests or the percentage time spent displaying stress behaviours during the tests between young and old dogs or between male and female dogs (see Appendix for means, test statistics and p values).

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4.2 Surveys

4.2.1 MDORS

Comparing the MDORS scores for rescue dogs (n = 30) and control dogs (n = 20) revealed no significant differences in the subscales Dog/Owner Interaction or Emotional Closeness. Rescue dogs tended to score higher than controls on the subscale Perceived Costs, but the difference was not statistically significant (Table 3). In addition, there were no sex differences or differences between young and old dogs (see Appendix). For rescue dogs, Perceived Costs was significantly negatively correlated with Emotional Closeness (r_s = -0.486, p = 0.019).

Table 3: MDORS scores for rescue dogs (n = 30) and control dogs (n = 20).

MDORS subscale	Rescue ($\bar{x}$ +/- 1 SE)	Control ($\bar{x}$ +/- 1 SE)	U	P-value
Dog/Owner Interaction	34.657 +/- 0.7657	34.435 +/- 0.8782	302.0	0.580
Emotional Closeness	40.767 +/- 1.1116	41.6 +/- 0.8752	297.0	0.952
Perceived Costs	17.547 +/- 0.907	15.3 +/- 1.5049	383.5	0.097

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4.2.2 DPQ

Comparing the personality traits, rescue dogs were reported as significantly more fearful than control dogs, scoring higher in the factor Fearfulness and the facet Non-social Fear (Table 5). In addition, they had a tendency to score higher than controls in Fear of Dogs, but the difference was not significant. Rescue dogs scored significantly lower than controls in the factor Activity/Excitability in addition to the facet Playfulness. Rescues also tended to score lower in Companionability, however, it was not statistically significant. In the factor Responsiveness to Training rescue dogs again scored significantly lower than controls, scoring significantly lower in the facet Trainability with a tendency to score lower in Controllability. While there was no difference between groups in the factor Aggression Towards People or Aggression Towards Animals, rescue dogs did score significantly higher in the facet Aggression Towards Dogs (Table 5 and Figure 9). There were no sex or age differences in DPQ scores (see Appendix).

Table 5: DPQ scores for rescue dogs (n = 30) and control dogs (n = 20). Significant differences are in bold type.

Factors and Facets	Rescue (x̄ +/- 1 SE)	Control (x̄ +/- 1 SE)	U	P-value
Fearfulness	**3.4 13 +/- 0.9185**	**2.8753 +/- 0.326**	**413.0**	**0**0.025**
Fear of People	3.548 +/- 1.00.992	2.875 +/- 0.3336	383.0	0.100
Non-social Fear	**3.8 +/- 0.218**	**2.983 +/- 0.134**	**480.0**	*****<0.001**
Fear of Dogs	2.878 +/- 0.2198	2.22 +/- 0.216	389.0	0.077
Fear of Handling	3.659 +/- 0.3261	3.21 +/- 0.4362	355.5	0.271
Aggression Towards People	2.444 +/- 0.244	2.0 +/- 0.3264	341.5	0.407
General Aggression	2.7653 +/- 0.301	2.1 +/- 0.3269	347.0	0.346
Situational Aggression	2.23 +/- 0.3266	2.01.91 +/- 0.3292	331.5	0.520
Activity/Excitability	**4.6553 +/- 0.2182**	**5.24 +/- 0.2198**	**185.0**	***0.023**
Excitability	3.438 +/- 0.3258	3.61 +/- 0.306	274.0	0.606
Playfulness	**4.03 +/- 0.3277**	**5.326 +/- 0.306**	**164.0**	****0.007**
Active Engagement	5.3293 +/- 0.238	6.05.94 +/- 0.21	216.5	0.097
Companionability	5.51 +/- 0.212	6.215 +/- 0.203	210.5	0.075
Responsiveness to Training	**4.988 +/- 0.2156**	**5.659 +/- 0.2194**	**162.5**	****0.006**
Trainability	**5.04.953 +/- 0.2**	**5.81 +/- 0.214**	**166.5**	****0.008**
Controllability	4.98 +/- 0.2195	5.436 +/- 0.215	204.5	0.058
Aggression Towards Animals	3.439 +/- 0.2199	2.988 +/- 0.22	380.5	0.111
Aggression Towards Dogs	**3.5 +/- 0.3283**	**2.438 +/- 0.237**	**427.0**	***0.012**
Prey Drive	3.53 +/- 0.3295	3.548 +/- 0.331	303.0	0.953
Dominance Over Other Dogs	3.14 +/- 0.211	2.877 +/- 0.301	364.0	0.204

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5. Discussion

The primary aim of this study was to determine if rescue dogs showed signs of long-term cognitive impairment due to past stress. The results of the study suggest that there are differences between rescue dogs and "normal" dogs in certain cognitive tasks, and that rescue dogs tend to display a higher level of stress-related behaviours. However, rescue dogs were expected to perform worse than controls in all four cognitive tests and this was not what was observed. While the rescue dogs performed significantly worse than control dogs in the Eye Contact test, they performed better than control dogs in Memory Test A, and did not differ from controls in either the Inferential Reasoning test or Memory Test B. In addition, performance in some of the tests and stress behaviours displayed during the tests were significantly correlated with certain aspects of the dog's personality and the dog's relationship with their owner as reported in the DPQ and MDORS respectively.

5.1 Eye Contact

On average rescue dogs maintained eye contact for shorter durations than control dogs. Several studies including Stewart et al., (2015) and Watowich et al., (2020) have used eye contact duration as a measure of cognitive executive functions including social engagement, inhibitory control, and delay of gratification. Reduced ability of dogs to maintain eye contact with their owner is a sign of cognitive decline due to ageing (Watowich et al., 2020) – as rescue dogs performed worse than control dogs regardless of age, this indicates cognitive impairment. Rescue dogs also tended to be more stressed during the eye contact test than control dogs. Nagasawa et al., (2015) showed that making eye contact with humans increases oxytocin levels in dogs. Oxytocin reduces stress reactivity in dogs (Buttner, 2016) so the higher durations of eye contact may account for fewer stress behaviours displayed by control dogs.

5.2 Inferential Reasoning

There was no difference between rescue and control dogs in the Inferential Reasoning test. Stewart et al., 2015 found that an average of 50% of dogs, or fewer, choose the correct cup during this test, possibly due to the dogs' misinterpreting the owner lifting the empty cup as a communication signal (Braeuer et al., 2006). However, in the present study, 71% of rescue dogs chose the correct cup, while 63% of control dogs chose the correct cup so it is not clear

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that the dogs were misinterpreting the test. Several studies have demonstrated a strong positive link between absolute brain size and executive functions (Shultz and Dunbar, 2010). Horschler et al., (2019) found that absolute brain size is a predictor of executive function in dogs, showing that dogs with larger brains performed better in several cognitive tests. However, they also found that the inferential reasoning test did not fit their model – brain size did not predict performance in this particular test. Hence, the lack of a difference between the rescues and controls in the present study may have been due to the nature of the test itself rather than a true reflection of cognitive abilities of the respective groups. Stress behaviours during this test were positively correlated with both Memory Test A and Memory Test B, indicating that rescue dogs that found any one of these tests stressful was likely to find the others stressful too.

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5.3 Memory Test A

Rescue dogs were better than control dogs at remembering where the treat was hidden in Memory Test A, which differed from the expected outcome. Dogs have been shown to retain information about hidden objects in their working memory for up to 240 seconds (Fiset et al., 2003). Hence, the delay interval of 60 seconds used in this study may have been too short to pose a challenge for the dogs' memory, however, Watowich et al., (2015) found results differed very little using 60, 90, and 150 second delay intervals.

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The superior performance of rescue dogs in the test may be explained by other factors. Rescue dogs had shorter durations of eye contact than control dogs which indicates lower impulse control, and also scored higher in "Fearfulness" on the DPQ. Jacobs et al., (2018) found that dogs with higher levels of impulsivity and fearfulness were more likely to display resource guarding behaviour. In addition, the fact that rescue dogs maintained eye contact for shorter durations than control dogs may indicate that human social contact is less important for them than for control dogs. Cook et al., (2016), demonstrated that most dogs find praise equally or more rewarding than food, but those that find food more rewarding are less likely to seek contact with their owner. While the life histories of the rescue dogs are unknown, it is possible that they may have come from situations where food was less plentiful than their current home. Therefore, rescue dogs may be more highly motivated than control dogs to keep track of potentially "scarce" food resources which may explain why they perform better than controls in remembering where food is hidden. While this is purely speculative, future studies could test this by using longer time intervals in the memory test, in addition to a questionnaire to establish

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if the dogs display resource guarding behaviour, and whether the dogs find food or human contact more rewarding.

Percentage time spend displaying stress behaviours during Memory Test A was negatively correlated with eye contact duration for both rescue dogs and control dogs – dogs that performed worse in the Eye Contact Test were more likely to find the memory test stressful. This may indicate that dogs that maintain less social engagement with their owners and have lower impulse control are also more stressed in a situation where they have to keep track of hidden food.

5.4 Memory Test B

This test differed from Memory Test A in that it was more complex and challenged the dogs in both working memory capacity and spatial memory (Piotti et al., 2017). Impairment in spatial memory can often occur even before impairment in executive functions, especially in older dogs (Head et al., 1995). Piotti et al., (2017) who developed the test, used number of tries to find the correct cup to measure performance in the test, however, they also suggested that a binary measure of success or failure might be a better measurement. In the present study both measurements were used, and no differences were found between rescues and controls, or between young and old dogs in either measurement (however, number of tries to find the correct cup was positively correlated with age). Poor performance in this test has been shown to be a sign of cognitive decline in ageing dogs (Piotti et al., 2017, Iotchev et al., 2020), therefore, the results of this test in the present study do not support the hypothesis of cognitive impairment in rescue dogs.

There was a negative correlation between number of tries to find the correct cup and number of training classes the dog had attended in the previous two years, indicating that dogs that had attended more training sessions were better at finding the treat in fewer attempts. Many dog training classes are centred around "nose-work" where the dog is trained to independently search for a particular scent in an area (Duranton and Horotitz, 2019). While the type of training classes the dogs attended is not known, this type of class is particularly popular in Sweden, so it is possible that these dogs have attended nose-work classes. While the dogs may have been using scent to locate the treat, Duranton and Horowitz (2019) argue that training dogs in nose-work allows them to act autonomously with their own initiative and helps in learning to analyse their environment and develop problem solving skills. This may account for the correlation observed.

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5.5 Dog-Owner Relationship (MDORS)

The MDORS survey measures three aspects of the relationship between a dog and their owner: Dog/Owner Interaction, Emotional Closeness, and Perceived Costs (Dwyer et al., 2006). There was a weak tendency for rescue dogs to score higher than controls in Perceived Costs. This was expected due to the higher prevalence of "problem behaviours" generally seen in rescue dogs - Vitulova et al., (2018) reported that 72% of dogs adopted from a shelter exhibited what the owners perceived as behavioural problems. The lack of any difference between rescues and controls in the MDORS subscales Dog/owner Interaction or Emotional Closeness indicates that the quality of a dogs' relationship with their owner is not affected by being a rescue, or by a slightly higher perceived cost. In addition, there was a negative correlation between Emotional Closeness and Perceived Costs – the closer the emotional bond between the dog and owner, the less likely the owner is to find the relationship difficult and highly costly. This suggests that a close emotional bond may help offset potential negative aspects of the relationship. Herwijnen et al., (2018) also found that dogs that scored higher in Perceived Costs scored lower in Emotional Closeness and Handlin et al., (2012) found that dog/owner dyads that reported higher Perceived Costs also had lower blood oxytocin levels (a hormone related to attachment and bonding (Uvnas-Moberg et al., 2005)) in both dog and owner.

5.6 Personality (DPQ)

Rescue dogs were reported as more fearful than control dogs. While Overall et al., 2019 found that fear negatively affected dogs' problem solving behaviour in cognitive tests, this was specifically in relation to fear of noises. In the present study, neither the factor Fearfulness nor any of its corresponding facets were correlated with eye contact duration, number of tries to find the treat in Memory Test B, or stress behaviours in any of the four tests so it is not clear what effect general fearfulness may have on the behaviour of dogs during cognitive tests.

Rescue dogs scored lower than controls in Activity/Excitability and its facets Playfulness and Active Engagement. This factor and these facets were all negatively correlated with stress behaviour during the Inferential Reasoning test indicating that rescue dogs that were less active and engaged may have found the test more stressful, however, there was no difference found between rescues and controls in performance or level of stress behaviours during this test . Roth et al., (2016) found that dogs that played more had lower concentrations of hair cortisol (a hormone related to stress (Selye, 1985)) which may account

for the lower levels of stress behaviours in dogs that scored higher in Activity/Excitability, Playfulness, and Active Engagement. In addition, the lower score in Active Engagement for rescue dogs coincides with the lower mean duration of eye contact indicating less social engagement in general.

Rescue dogs scored lower than controls in the factor Responsiveness to Training, and its facet Trainability. Bray et al., (2017) found that poor performance in cognitive measures such as problem-solving abilities and perseveration were associated with guide dog candidates failing out of training programs, suggesting that lower cognitive capabilities are related to reduced trainability. From this it could be inferred that lower trainability is a potential sign of reduced cognitive functioning, however, these DPQ scores were not correlated with performance in the tests so further research would be required to confirm this. Rescue dogs being less trainable may also be accounted for by other factors such as lack of training in early life, but as the life histories of the dogs are not known this is purely speculation. Breed differences may also have had an effect, however, there were 21 mixed breeds and of the 29 pure breeds no breed had more than two individuals (see Table 1), therefore it was not possible to group dogs by breed for statistical analysis.

Rescue dogs scored higher than controls in Aggression Towards Dogs, however, this facet was not correlated with stress behaviours or performance in any of the tests and it is not clear what connection, if any, there may be between aggression and cognitive performance. Dogs adopted from shelters often display some form of aggressive behaviour, with a quarter, or more, of owners reporting aggression as a behavioural problem post-adoption (Vitulova et al., 2018, Yang et al., 2020). Interestingly, there was no difference between rescue and controls in any of the other aggression-related factors or facets – investigating the specific types of aggression displayed in rescue dogs could be an area for further research.

5.7 Limitations

The main limitation in the study was the difficulty level for the dog owners. In most citizen science studies about dogs, dog owners simply complete a questionnaire or in some cases, such as in the tests on *Dognition.com* the owners self-report the results of cognitive tests they perform at home (Stewart et al., 2015). In the present study, the owners were required to film the tests, upload the video files to a Microsoft One Drive folder, and rename the files. Several owners had technical difficulties in one or several of these steps. In email communications with several of the owners I learned they had performed and filmed the tests

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but never uploaded them after encountering technical difficulties. The tests were quite simple, and owners were given extensive instructions; despite this, the number of steps involved, the difficulty of performing and filming the tests, and technical issues resulted in only 47 owners submitting videos out of a total of 228 that filled out the MDORS questionnaire. Of these 47 owners only 32 performed and submitted all 4 cognitive tests, indicating a very steep fall-off in completion of the study.

Another limitation in the study was the reliance on dog owners to do all the tests themselves without a scientist present. As the tests were being performed by the owners, in the owners homes it was impossible to have a standardized the test area and control for various potential distractions. Time of day, the order of the tests, and whether they were all performed on the same day or over several days were decided by the owner and all these factors could have influenced the performance on the tests. Some of the owners filmed the tests outdoors, some videos had other dogs, cats, or children present while the test was being carried out. In many of the videos the dog was not on screen for long portions of the video. This led to the decision to record stress behaviour as the percentage time the dog spent displaying any stress behaviour while on screen which may not have been indicative of the dogs' actual level of stress behaviours. Despite these limitations I believe that stricter criteria for controlling all these factors would have led to an even steeper fall-off in the number of videos uploaded and therefore much less data.

5.8 Further Research

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For future studies I would recommend performing the tests with the dogs in a standardized test arena with the experimenter present to ensure consistency in the tests, record all stress behaviours, and control for distractions. While this may result in less data being collected overall, the data may lead to a more accurate reflection of the actual cognitive capacities of rescue dogs. If the results of the tests done with the dogs in person are consistent with the current study, confirming its accuracy, then future studies could use citizen science methods for larger sample sizes.

Longer delay intervals for the memory tests would be a more robust test of the dogs' actual working memory capacity. Additional questionnaires about the background of dogs that provide information on resource guarding behaviour and how rewarding the dogs' find food vs social contact would be useful for clarifying the results of Memory Test A.

5.9 Conclusion

Rescue dogs show some signs of cognitive impairment compared with non-rescued dogs, particularly in their ability to maintain eye contact with their owner. However, they perform better than controls in a simple memory test. Still, the design of the tests may need to be reconsidered and performed with the dogs in person in order to obtain more accurate data on potential cognitive impairment in rescue dogs, and to assess the viability of the citizen science method used in this study.

6. Societal & Ethical Considerations

Dogs are the oldest and most common of human companion animals. Dog ownership is increasing, especially ownership of rescued dogs. This study and others have shown that there are clear differences in the behaviour of rescued/rehomed dogs compared with the rest of the general dog population, however, these differences are not well understood. While dog ownership has many health benefits for the owner (both psychologically and physically) the link between the health and well-being of both parts of the dog-owner dyad is becoming more clear – for example it has been shown that dogs mirror their owners' stress levels. Therefore, it is important for the welfare of both rescue dogs and their owners that we better understand their behavioural needs which starts with understanding how their behaviour differs from that of "normal" dogs and what the underlying mechanisms of these differences are.

During the Covid-19 pandemic many more people than usual acquired new pets (especially dogs) to deal with the boredom and social isolation that was ubiquitous during this time. People who did not have room in their lives for dogs before the pandemic are unlikely to have room for them once the pandemic is over. It is therefore likely that many of these dogs may be rehomed in some fashion – whether they are given to family or friends, relinquished to shelters, or simply abandoned. This will lead to an even greater increase in the number of rescue dogs that need homes. Hence, it is more crucial than ever that we begin to understand the potential cognitive impairments and different behavioural needs of rescue dogs.

7. Acknowledgements

Firstly, I would like to thank my supervisor Lina Roth for her help and advice throughout the entire process. I'd like to thank all the dog owners who participated in the study as well as all the dogs who did the tests (with a special thanks to Dante and Lily). I would like to thank my parents and siblings for all their love and support, especially in the last year. Lastly, I'd like to thank Renate Larssen for her help, support, and encouragement.

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Appendix

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The following are links to the Microsoft Sway pages containing the instructions for the experiment. These were provided to owners in the open calls, with different links for rescue dogs and control dogs. The instructions were available in both Swedish and English. The Microsoft Sway pages contain some background information about the project, links to the online MDORS and DPQ, detailed step-by-step written instructions for each of the four tests, as well as diagrams and videos of the tests being performed.

Rescue Dogs (Swedish):
https://sway.office.com/86EmZ561OZJZFRG6?ref=Link&loc=play

Rescue Dogs (English):
https://sway.office.com/Py2IJaNmGhDuHLFk?ref=Link&loc=play

Control Dogs (Swedish):
https://sway.office.com/RcgcJGu5uWPzkxME?ref=Link&loc=play

Control Dogs (English):
https://sway.office.com/p1szkBsZfYVmwO1e?ref=Link&loc=play

MDORS data for all respondents

Analysis of the data for all 248 survey respondents revealed no significant differences between rescue dogs (n = 141) and control dogs (n = 107) in any of the 3 subscales (Table X).

Table X: MDORS scores for all 248 dogs (rescue dogs n = 141, control dogs n = 107).

MDORS subscale	Rescue ($\bar{x}$ +/- 1 SE)	Control ($\bar{x}$ +/- 1 SE)	U	P-value
Dog/Owner Interaction	35.8 +/- 0.354	35 +/- 0.399	8349	0.149
Emotional Closeness	41.62 +/- 0.502	41.69 +/- 0.527	7572.5	0.959
Perceived Costs	16.26 +/- 0.427	15.83 +/- 0.469	7899.5	0.524

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Young dogs (n = 137) overall scored significantly higher than old dogs (n = 111) in Perceived Costs ($p < 0.001$) (Figure X). Old dogs ($\bar{x}$ = 34.85 +/-0.425 SE) tended to score higher than young dogs ($\bar{x}$ = 35.95 +/-0.331 SE) in Dog/Owner Interaction (U = 6649.5, p = 0.088) and Emotional Closeness ($\bar{x}$ = 42.52 +/-484 SE and $\bar{x}$ = 40.95 +/-0.524 SE respectively) (U = 8640.5, p = 0.064), however, the differences were not statistically significant. Males and females did not differ in any of the subscales.

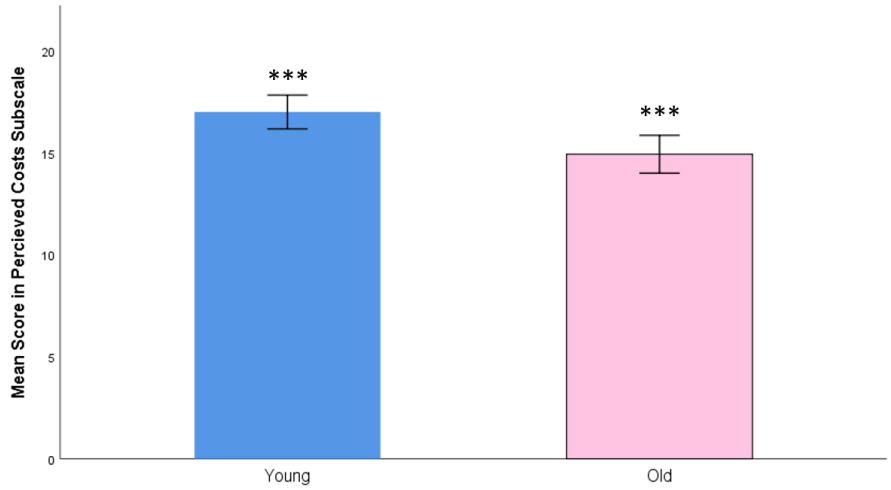

Figure X: Mean score of young dogs (n = 137) and old dogs (n = 111) in the subscale Perceived Costs of the MDORS with all 248 respondents ***p<0.001.

DPQ with all respondents

There were no significant differences between rescue dogs and control dogs for any of the 5 main Factors in the DPQ with data from all respondents (n = 228). Rescue dogs scored significantly lower than controls in the facets Non-social Fear and Controllability (Table X).

Table X: DPQ scores for rescue dogs (n = 128) and control dogs (n = 90).

Factors and Facets	**Rescue ($\bar{x}$ +/- 1 SE)**	**Control ($\bar{x}$ +/- 1 SE)**	**U**	**P-value**
Fearfulness	3.6 +/- 0.06	3.4 +/- 0.07	6644.5	0.054
Fear of People	3.46 +/- 0.098	3.17 +/- 0.11	6657	0.05
Non-social Fear	3.93 +/- 0.064	3.57 +/- 0.08	7336.5	**0.01
Fear of Dogs	3.34 +/- 0.08	3.31 +/- 0.93	5467	0.704
Fear of Handling	3.69 +/- 0.106	3.65 +/- 0.13	5934	0.501
Aggression Towards People	3.41 +/- 0.084	3.27 +/- 0.1	6067.5	0.081
General Aggression	2.78 +/- 0.09	2.53 +/- 0.09	6555	0.957
Situational Aggression	4.04 +/- 0.116	4.01 +/- 0.14	5784	0.117
Activity/Excitability	4.52 +/- 0.056	4.71 +/- 0.071	5042	0.117
Excitability	4.02 +/- 0.1	4.1 +/- 0.12	5635.5	0.786
Playfulness	3.73 +/- 0.08	3.97 +/- 0.114	5067	0.129
Active Engagement	5.6 +/- 0.106	5.81 +/- 0.114	5259	0.273
Companionability	4.7 +/- 0.08	4.94 +/- 0.104	5071.5	0.132
Responsiveness to Training	4.74 +/- 0.054	4.9 +/- 0.075	5058.5	0.125
Trainability	4.96 +/- 0.071	5.26 +/- 0.08	4659	*0.016
Controllability	4.52 +/- 0.08	4.54 +/- 0.11	5774	0.976
Aggression Towards Animals	3.8 +/- 0.06	3.7 +/- 0.08	6269.5	0.266
Aggression Towards Dogs	3.9 +/- 0.08	3.62 +/- 0.1	6254.5	0.279
Prey Drive	4.24 +/- 0.102	4.12 +/- 0.108	6297	0.24
Dominance Over Other Dogs	3.37 +/- 0.08	3.36 +/- 0.106	5760	1

Male dogs (n = 96, $\bar{x}$ = 3.51 +/-0.087 SE) scored significantly higher than female dogs (n =113 $\bar{x}$ = 3.24 +/-0.9 SE) in the facet Dominance Over Other Dogs (U = 6476, p = 0.015). Males and females did not differ in any other Factor or facet (see Appendix). Young dogs (n = 115, $\bar{x}$ = 4.7 +/-0.05 SE) had significantly lower scores than old dogs (n = 94, $\bar{x}$ = 4.96 +/-0.075 SE) in the Factor Responsiveness to Training (U = 6615, p = 0.005) and its facet Controllability ($\bar{x}$ = 4.38 +/-0.079 SE and $\bar{x}$ = 4.71 +/-0.114 SE respectively) (U = 6356.5, p = 0.028). In addition, young dogs ($\bar{x}$ = 3.667 +/-0.08 SE) scored significantly lower than old dogs ($\bar{x}$ = 3.86 +/-0.112 SE) in the facet Aggression Towards Dogs (U = 6515.5, p = 0.01). There were no other significant differences between young and old dogs.