Evaluating the relationship between canine cognition and the strength of the human-canine bond
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I. Abstract

The objective of this study is to evaluate the relationships between canine cognition and the human (*Homo sapiens)*-domestic dog (*Canis lupus familiaris)* bond. *C. lupus familiaris*, was domesticated between 20,000 and 40,000 years ago, and evidence continues to be generated regarding the date of domestication. Due to a relationship of companionship, loyalty, and friendship, "man's best friend" was attributed to the domestic dog. Domestication is associated with an increased ability to understand social and environmental cues compared with the wild counterpart and direct ancestor of *C. lupus familiaris*, the gray wolf (C. lupus). Based on physiological, behavioral, and morphological changes, the domestic dog developed close relationships with humans. Recent studies also suggested domestication can be described as "survival of the friendliest". Additional studies questioned how these changes related to the alliance between dogs and their human companions. The present research serves to elucidate the coevolution and subsequent interconnectedness between canine cognition and the human-dog bond.

Keywords: Bond; Canine; Cognition; Dog; Domestication; Human; Relationship

II. Introduction

Purugganan (2022) described the domestication of *Canis lupus* (specifically, the gray wolf), to *C. lupus familiaris* (the modern domestic dog) in two phases. Domestication was a coevolutionary process derived from a mutualism, which can be described as beneficial interactions between two individuals of different species. Under this mutualism,

one species was considered the domesticator, providing an environment rich in resources, and increasing the reproductive fitness of another species, the domesticate. This relationship formed the first phase of *C. lupus familiaris* domestication. Paleolithic humans and wolves developed a mutualistic relationship resulting from similar hunting patterns (Tancredi and Cardinali, 2023). This cooperation provided an easily achievable food source for humans and wolves, resulting in a positive outcome for both species.

Homo sapiens selected for desirable traits in plants and domestic animals for thousands of years, which contributed to human success. This was the second phase of *C. lupus familiaris* domestication following the establishment of a mutualistic relationship between *H. sapiens* and *C. lupus*. *C. lupus* underwent a process of self-domestication in which the friendliest wolves gained an advantage (Handwerk, 2018). Self-domestication is the process where a species becomes domesticated as a product or by-product of natural selection. Early humans unintentionally selected traits involving tameness and submission (Belyaev, 1979). An experiment conducted by Belyaev (1959) intentionally selected tamer wild foxes for breeding (Bidau, 2009). In return, later generations exhibited friendly behavior with humans due to neuroendocrine ontogenetic modifications. This study demonstrated unconscious selection by humans promoted mutualism and self- domestication. Through self-domestication, *C. lupus* became comfortable with humans and wolves were able to maintain relationships with humans in future generations. Changes in hormonal levels helped facilitate the coevolution between humans and *C. lupus familiaris* during this period of self-domestication. Higher cortisol and oxytocin levels in some wolves resulted in favorable social behaviors which in turn caused humans to desire individuals exhibiting these attributes (Herbeck et al. 2021).

Tonoike et al (2022) reported increased cortisol was an important turning point in domestication. This hormone regulated social cognition, fear response activation, and assisted the domestic dog in assessing social situations and reacting accordingly. Social cognition refers to the process of storing information in relation to memory, interpretation, and response. In addition to cortisol, oxytocin was favored in natural selection due to its role in forming emotional attachments (Tonoike et al, 2022). *C. lupus* and their progeny exhibited increased oxytocin levels, which was vital in developing the human-domestic dog bond and the oxytocin gaze loop. Wolves exhibiting increased oxytocin levels formed closer bonds with humans and became more desirable, increasing their survival chances and procreation. Nagasawa et al. (2015) demonstrated when domestic dogs gaze at their human companions, human oxytocin levels increase, and the human shows their dog more affection. This affection subsequently increases the dog's oxytocin level and completes the oxytocin gaze loop. The gaze loop strengthens the emotional bond between a human and their domestic dog by building a social connection. Furthermore, Tonoike et al. (2022) reported the endocrine system development during human-domestic dog coevolution was associated with advanced *C. lupus familiaris* cognitive ability.

Virányi et al. (2008) compared the domestic dog and its precursor, the gray wolf to determine similarities and differences in their cognitive abilities. Two groups of four-month-old puppies, including nine gray wolves (*C. lupus)*, and eight domesticated dogs (*C. lupus familiaris)* were intensively socialized. Each puppy spent 20-24 hours in close contact with humans. A third control group of nine puppies (*C. lupus familaris)* was raised in an average home pet environment. An average environment for a pet dog

includes ~12-16 hours of proximity to humans. This group served as the baseline for an average dog's socialization. Performance was tested following human cues, such as pointing, hand clapping, and eye contact. Results showed no significant difference between *C. lupus familaris* puppies raised with intensive socialization and *C. lupus familiaris* puppies raised in a family home environment, indicating socialization in early life stages was not an accurate indicator to determine a domestic dog's cognitive abilities. However, wolves showed decreased response to pointing gestures compared to both puppy groups. Results of this study provided evidence coevolution and domestication played a substantial role in shaping the domestic dog's cognitive abilities.

Morrill et al. (2022) demonstrated human-dog coevolutionary processes resulted in increased cognitive abilities in the domestic dog, however, no significant differences were detected among breeds. This study showed breed was not a reliable indicator in determining an individual's behavior and sociability. The community service project titled "Darwin's Ark" included 18, 385 dogs of varying breeds with approximately 49% purebred. Results showed 9% of behavioral variation was attributed to breed and no significant differences were detected between purebreds and "mutts", the latter a term assigned to dogs that were a combination of two or more breeds, for traits related to cognitive ability. Therefore, breed did not predict a dog's disposition and was not a reliable behavioral measurement.

Breed and socialization in early domestic dog developmental stages were not significant in determining cognition, however age was vital in measuring the domestic dog's cognitive abilities. Bray et al. (2021) assessed different aged dogs on several cognitive functions including memory and inhibitory control. A group of domestic dogs

was evaluated at nine weeks and 21 months of age. Results showed dog older than 12 months were more successful at tasks such as responding to finger cues, exhibiting inhibitory control, and problem solving, suggesting age can be an accurate factor in measuring cognition.

Cognition is the acquisition, processing, and interpretation of information and the subsequent response to that information. *C. lupus familiaris* uses cognition to adjust to social environments such as a household or public space. Obedience is the most documented and accepted means to measure a dog's cognitive abilities (Bray et al, 2021). Carballo et al. (2020) demonstrated assistance and therapy dogs exhibited higher cognitive abilities due to subsequent training associated with working dogs. Bray et al. (2021) suggested a dog's ability to obey commands, ignore positive or negative stimuli, and learn rapidly were all attributes of an obedient dog which correlated with increased cognition. Furthermore, problem solving, understanding finger cues, and memory were also traits, which could be measured to appropriately gauge a dog's cognitive abilities. Canine biddability is the capability to be trained. High levels of biddability positively correlated with a domestic dog's ability to be obedient (Bray et al, 2021). Udell and Brubaker. (2016) previously suggested highly trained dogs were better problem solvers and exhibited a more rapid response to stimuli compared to untrained dogs. The American Kennel Club (AKC) described dogs with high cognitive abilities, exhibiting tendencies to get into trouble when regularly under stimulated (Gibeault, 2023). Boredom in these dogs can result in property destruction which stems from a lack of mental stimulation.

C. lupus familiaris was the first species to enter a domestic relationship with *H. sapiens,* the first species to coevolve with humans, and the first to self-domesticate in the

absence of human artificial selection to adapt to the social environment (Bidau, 2009). Nagasawa et al. (2009) demonstrated beneficial physical and psychological bonds between humans (*H. sapiens)* and dogs (*C. lupus familiaris),* showing the advantages of *C. lupus* domestication and increased proximity to humans. Wolves were first domesticated for numerous reasons, the most notable compassion and dependency. Indigenous people often took pity on wolf pups abandoned by their mothers (Pierotti and Fogg, 2017). In other cases, sick, injured, or old wolves relied on humans for food.

Part of canine evolution was the development of breed differences. A strong selective pressure was asserted on domestic dogs which led to the accumulation of genetic and phenotypic differences (Galibert et al. 2011). Most breed differentiation occurred in the Medieval and Renaissance periods, when initial *C. lupus familiaris* deviations were based on the services breeds provided, e.g. protection or herding (Adejumobi et al, 2023). Breed differentiation helped further the mutualistic relationship between *C. lupus familiaris* and *H. sapiens.* Domestic dogs used for hunting evolved to have a better sense of smell and agility while dogs used for protection evolved to have larger muscles and stature (Svartberg, 2006). Herding dogs such as border collies and German shepherds became distinguished from working dogs such as boxers or rottweilers. Today, domestic dogs are trained to provide humans numerous services, including using their advanced olfactory senses in canine scent detection. *C. lupus familiaris* are trained to detect drugs, bombs, disease, e.g. COVID-19 variants, cancer, diabetes, and seizures. Dogs are also trained to provide mental health support, e.g. PTSD and bipolar disorder. A dog and its human companion are given a sense of mental security and physical safety.

The attachment between a human and domestic dog closely resembles the relationship between a mother and child (Karl et al. 2020). Domestic dogs are dependent on human care and dogs appeal to their caregiving nature. This dependency for food, water, and shelter prompts humans to feel responsible for domestic dogs, similar to a child (Gee et al., 2021). The Canine Behavioral Assessment and Research Questionnaire (C-BARQ) is one tool employed to measure a dog's attachment to its human companion. Thielke and Udell (2019) described dog-human attachment as secure or insecure through a study that demonstrated dogs with a secure attachment sought proximity to their human companion and showed positive reactions to physical contact. Alternatively, dogs with an insecure attachment might hide from humans and exhibit distress when confronted with physical contact. The C-BARQ questionnaire asks humans to rate their dog(s) on specific behavioral attributes, e.g. aggression, fear, and attention-seeking. Dogs who exhibited reduced aggression and fear and, increased attention-seeking behavior were considered to have a secure human attachment, and therefore a strong human-canine bond. Dogs who exhibited increased aggression and fear, with decreased attention-seeking behavior were regarded to have a weak human-canine bond attributed to an insecure human attachment.

III. Null Hypothesis

Ho: No relationship exists between canine cognition and the human-canine bond.

IV. Methodology

Literature Review

I will conduct a scoping review to ascertain the body of literature on the relationships between canine cognition and the human-domestic dog bond. This review

will provide a clear indication of the scope of the peer reviewed literature, i.e., studies available and an assessment of the research, i.e., broad or detailed. This type of literature research is best suited to investigate the seminal through any emerging evidence in the field. Specifically, this scoping review will examine domestic dog cognition. I will also review the role coevolution and domestication (i.e., self-domestication and artificial selection) played in the relationship to the human-dog bond. Primary peer reviewed scientific journal articles will be included in the search. I will use the following databases and search terms, respectively: https;//scholar.google.com/, worldwidescience.org, researchgate.net, PubMed, and Web of Science; Bond, Canine, Cognition, Obedience, Dog, Domestication, Human, Relationship. I will evaluate the credibility and quality of my sources to ensure the information is reliable by employing research conducted and published or referenced within the last fifteen years. The scoping review is a qualitative assessment of my research topic. The review on cognition and the human-domestic dog bond will provide the basis for my survey (see below).

Survey

In addition, a survey, will be distributed to humans with a canine companion to evaluate the relationship between canine cognition and human attachment. The survey platform Prolific (https://www.prolific.com/) will be used to distribute the questionnaire. All participants are vetted by Prolific and provided a monetary incentive for their contribution to the research. The questionnaire will assess canine cognition in relationship to the human-dog bond, measured by the response to human proximity self-reported by the respondents. A modified C_BARQ survey will be created via Qualtrics, imported to Prolific, and distributed via Prolific to a random sample of participants

(N=350). The survey will be a representative sample and will therefore require IRB approval.

Data Analyses

My analyses will evaluate *C. lupus familiaris* cognition and attachment to human companions. To evaluate cognition, I will include a range of survey questions, including human companion demographics, dog age and response to cues (Questions 1-5; Appendix I). I will include behavioral questions regarding aggression and anxiety to evaluate attachment. Questions 5-9 on the survey assess cognition by measuring intelligence and obedience (Appendix I). I will use a Likert point system, i.e. 1-5 to calculate cognition, the higher the number the better the cognition. Questions five, six, and nine are answered on a scale of one to five. Yes and no questions will be entered as binary data, such as questions eight and nine, where an answer of yes will be answered as 1 and an answer of no will be entered as 0. Calculating the human-canine bond will also be analyzed using binary and the Likert system.

I will use various statistical methods to evaluate the relationship between cognition and the human-dog bond. The Prolific survey responses will be exported to Excel for subsequent analyses in the data analysis software PAST. I will initially conduct basic statistics tests to determine if the data violates normality assumptions. However, given the large dataset, distributions tend to be normal and parametric procedures can be employed. A Principal Component Analysis (PCA) will be conducted to reduce the data into smaller subsets of variables to observe trends and outliers. A scree test will determine if a PCA is compatible with the data collected from the survey. The scree plot will show the eigenvalues for each primary component. It will determine which

components explain the variability in the data. I will then conduct a Pearsons Correlation

Analysis, which will establish the strength of a relationship between two values. A

Pearsons Correlation coefficient (r) close to a value of 1 (r-value = 1) indicates a perfect

positive correlation while an r-value of -1 indicates a perfect negative correlation. A

Pearson's correlation r-value = 0 indicates the absence of a correlation. Next, an

Unweighted Pair Group Method With Arithmetic Mean (UPGMA) will be conducted.

UPGMA is a hierarchical clustering method, which clusters variables based on distance.

The UPGMA algorithm generates a rooted dendrogram. This analysis should support the

PCA. Finally, a Multivariable Analysis of Variance (MANOVA) will be performed to

determine if significant differences exist among the variables.

V. Expected Results

I will compare the survey results to the scoping review to ascertain any qualitative

relationship between domestic dog cognition and the human-dog bond. The Principal

Component Analysis (PCA) will serve to reduce the dimensionality of the larger dataset

while conserving relevant statistical information. The PCA will aid in elucidating any

tends, clusters, or outliers in my survey response data and explain the degree of

variability. For example, older dogs that exhibited quick responses to finger and

environmental cues will be categorized as having a high level of cognition. Dogs that

exhibited low levels of aggression and anxiety will be categorized as having a more

secure attachment to their human companions. The PCA and UPGMA will cluster these

individuals together. The Pearson's Correlation Analysis will determine the strength and

direction of a relationship between variables. I expect to find a positive and strong

correlation (r-value) between a dog's cognitive abilities and the strength of its

relationship to their human companion. I expect dogs exhibiting increased cognitive abilities will also exhibit a heightened and secure attachment, based on the r-value, to their human companion.

VI. Conclusion

My research will involve reviewing past research, including the seminal through current peer reviewed studies, and distributing a survey based on a modified C-BARQ questionnaire to assess the relationship between canine cognition and the human-dog bond. I will not consider breed due to recent evidence suggesting breed does not contribute to behavioral traits (Morrill et al., 2022). I will include dog biddability, obedience, and age to determine cognition level. I will assess response to human proximity to measure human attachment levels. I expect to reject my null hypothesis: no relationship exists between canine cognition and human attachment.

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Appendix I

Survey:

1. Gender: __ Male __ Female __ Other __ Decline to answer

2. Age: __ 18-28 years old

   __ 29-39 years old

   __ 40-50 years old

   __ 51-61 years old

   __ 62-72 years old

   __ 73+ years old

3. How long have you had your dog? _____

4. How old is your dog? _____

5. On a scale of one to five, when you verbally ask your dog to perform a task

   approximately how often does he/she respond? (never) 1___ 2___3___4___5___

   (always)

6. Approximately how long does it take for your dog to react when given a non-verbal

   cue? (ex: sit)

   (doesn't respond) 1___ 2___ 3___ 4___ 5___ (immediately)

7. If you point to an object, will your dog follow your finger and look at the object?

   __yes __no

8. If you pick up your dog's leash without saying a word, does your dog get excited?

   __yes __no

9. Does your dog tend to get into trouble or be destructive when left alone?

   (never) 1___ 2___ 3___ 4___ 5___ (always)

10. On a scale of one to five, how aggressive is your dog when presented with an

    unfamiliar person? (not aggressive) 1___ 2___3___4___5___ (very aggressive)

11. On a scale of one to five, how aggressive is your dog when presented with an

    unfamiliar dog? (not aggressive) 1___ 2___3___4___5___ (very aggressive)

12. On a scale of one to five, how anxious is your dog around an unfamiliar person?

    (not anxious) 1___ 2___3___4___5___ (very anxious)

13. On a scale of one to five, how anxious is your dog in the presence of a loud or sudden

    noise? (not anxious) 1___ 2___3___4___5___ (very anxious)

14. On a scale of one to five, how often does your dog linger around you?

    (never)1___ 2___3___4___5___ (always)

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