Canis familiaris; Laterality of the Dog

by
Mariel Mingola

Purchase College,
State University of New York

Sponsored by: Dr. Lee Ehrman

Second Reader: Dr. Daniel Hochman, Grove Street Veterinary

Table of Contents

Abstract

The modern dog, Canis familiaris, comes in all shapes and sizes but for thousands of years has served one main purpose, as man's best friend. This bond, established between human and dog, dates back tens of thousands of years, and established a relationship of mutualism, both giving and receiving care from one another. Archeological, genetic and genomic studies provided insight into how the modern dog evolved from their ancestral origin dating back to the gray wolf. Evolution is defined changes in heritable characteristics over time, giving rise to biodiversity in all living things. These changes over time are driven by mutation, alteration of a gene; natural selection, a varied path resulting in survival of the current fittest; and genetic drift, random variation of genotypic frequencies in small populations. However, through thousands of years of domestication, Canis familiaris has been further sculpted to fit individual needs whether it be cosmetic, accessory, working or protection purposes. Sharing the same newly adapted environment as humans with similar medical care makes them models for genetic research. Given that humans, Homo sapiens sapiens, are just a small notch on the evolutionary tree, it should be of no surprise the extraordinary similarities we have to all vertebrates (and even invertebrates). Ongoing research of early development, molecular biology, genetics and genomics bridges gaps in what is known about the animal kingdom. My study focused on the lateralization of Canis familiaris in comparison to other vertebrate lateralization, specifically on preferential pawedness.

Introduction

"Seen in the light of evolution, biology is, perhaps, intellectually the most satisfying and inspiring science. Without that light, it becomes a pile of sundry facts -- some of them interesting or curious but making no meaningful picture as a whole (1972)," said Ukrainian-American geneticist, evolutionary biologist and founder of the modern synthesis, Theodosius Dobzhansky . In today's society, Darwin's theory of evolution is scientifically undeniable and undoubtedly the single greatest advancement in any field of biology. Evolution is defined as changes in heritable characteristics over time, giving rise to biodiversity in all living things. Over time, these changes are driven by mutation, alteration of a gene; natural selection, a varied path resulting in survival of the current fittest; and genetic drift, random variation of genotypic frequencies in small populations. Discoveries paint the path to our history with fossilized records and DNA analysis, telling us a story of how our modern world came to be. Elegant examples of historical evolution have been found in the form of transitional fossils, displaying forms as intermediates between ancestor and progeny. Some examples of these transitional fossils include Archaeopteryx and the Tiktaalik, two of the first transitional fossils ever found (Hecht, 2013). However, evolution isn't just shown in fossil form. There are plenty of profound examples such as the comparison of finch beaks (Uppsala University, 2015), endosymbiosis of bacteria (Nowack and Melkonian, 2010), or the more common, relatable subject, domestication of canines.

The bond established between human and dog dates back tens of thousands of years, an established relationship of mutualism, both giving and receiving care from one another. In addition to emotional benefits, a bond shared between human and dog improves one's physical and mental health by reducing stress, lowering blood pressure, helping prevent heart disease, helping fight depression and more (Dotson and Hyatt, 2007). Scientific studies suggest domestication began approximately 18,800-32,100 years ago (Thalmann, et al., 2013) with genetic evidence collected from East Asia, Europe and Siberia. Early on, dogs have been considered 'man's best friend,' acting as companions both at home and work, and even as lap dogs, such as seen with Roman's (O'Neill and Packer, 2016). Furthermore, archeological evidence shows dogs being buried next to respective humans; and according to chemical analyses of dog bones, some dogs also shared the same diet. During the first Canine Behavior and Genetics Conference in London, 2015, US geneticist Heidi Parker was quick to point out that modern dogs are considered good models for human genetics because of their common environments and similar medical care (O'Neill and Packer, 2016).

Given that humans (*Homo sapiens sapien)* are just a small notch on the evolutionary tree, it should be of no surprise the extraordinary similarities we have to all vertebrates (and even invertebrates). The ongoing research of early development, molecular biology, genetics and genomics bridges gaps in what is known about the animal kingdom. Symmetry/lateralization is hereditary, passed down to progeny, grouping species onto phylogenic trees. Connections have been studied and "over the last decade, it has become clear that behavioral lateralization is not restricted to humans, but a fundamental principle of the organization of behavior in vertebrates…its knowledge is important in understanding developmental plasticity, function and evolution of lateralization, and its relationship with developmental disorders" (Schaafsma, Riedstra, Pfannkuckem, Bourma and Groothuis, 2008).

I have focused my senior project, on motor lateralization of *Canis familiaris*, specifically concentrating on preferential frontal pawedness. This phenomenon is well studied in humans but less so in the canine species; however, there is a "growing body of literature on canine motor lateralization, focused mainly on behavioral lateralization in the form of forelimb preferential use…[Furthermore,] motor lateralization in dogs is [considered to be] stable between breeds…but variable between sexes…There have [also] been several recent studies that revealed an interesting association between emotional functioning and limb preference" (Siniscalchi, d'Ingeo and Quaranta, 2017). "It is well established that there is a complementary specialization of the two sides of the brain in terms of spatial attention, so that the right hemisphere processes information from the left visual field, and the left hemisphere processes information from the right visual field…In addition, paw preferences in canine species has also been associated with functional differences at both behavioral and physiological levels," (Siniscalchi, d'Ingeo, Fornelli and Quaranta, 2016). Assessments of limb/paw preference in the canine species involves observing specific tasks, such as the widely popular Kong test, which involves the stabilization and retrieval of food inside a round toy; the removal of tape from the ventral surface of the nose; paw shaking; and the advancing paw and also considered factors such as age, weight, sex, breed, and reproductive status.

Materials

- 73 Domestic dogs of varied breeds
- Dog treats
- Classic Kong ® Dog Toy
- Peanut butter
- Blue Masking Tape

Methods

Participants included a pool of 73 dogs and their owners who were approached through a local apartment community. Owners were given information about this study, provided consent and demographic backgrounds of their dog, including ages, weights, sex, breeds and reproductive statuses. Tests were performed in an apartment or at a quiet local park steps from the veterinary office. Tests include a tape test, where a piece of tape was placed on the anterior part of the muzzle and observations of preferred paw to attempt to remove the tape were tallied and recorded; the Kong ® test, where a treat was placed inside the rubber cone and observations of the preferential paw used to stabilize the toy were tallied and recorded; and lastly, the advancement of paw/limb from the seated position were tallied and recorded. All tasks were performed for a short period, no longer than 10 minutes per each test, upon the dog's discretion.

Examination of each dog was done only once and determination of paw preference differed for each task. During the tape test, a tally of which paw was used to try and remove the tape was taken. Distinct discretion was used to determine whether the movement of the paw was used to remove the tape or simply to step, walk or roll. Only movements for tape removal were tallied. The Kong ® test was tallied by the leading paw. For example, the first paw to be used to stabilize the Kong ® would be tallied, and if a second paw followed, resulting in both paws used stabilize the toy, the second paw would not be taken into consideration. Once both paws were removed or adjustments to the Kong ® were made, the next leading paw would be tallied. Observations of sit to stand were determined by the leading paw from the seated position. In some cases, dogs would use their hind legs, keeping their front paws stationary. These circumstances were not taken into consideration. After all data was collected, tallies were then calculated into frequencies and compared.

Results

Table 1.

Breed	Neutered	Sex		< 1 y	1 to 3	3 to 6	6 y <	Stand from sit		Kong stablization		Tape		Left Total	Right Total	Left Freq	Right Freq
		M	F					Left	Right	Left	Right	Left	Right				
Bermese Mountain Dog	Yes		2			x		0	4	0	0	2	1	2	5	0.29	0.71
Boston Terrier	Yes	1					x	1	4	3	7	3	9	7	20	0.26	0.74
Boxer	Yes		2					1	3	2	4	0	9	3	16	0.16	0.84
Boxer	Yes	1			x			3	0	2	0	5	2	10	2	0.83	0.17
Boxer	Yes		2			x		0	1	3	3	0	7	3	11	0.21	0.79
Brittney	Yes		2		x			0	3	2	5	4	4	6	7	0.46	0.54
Brittney	Yes		2				x	0	3	1	3	1	7	2	13	0.13	0.87
Bulldog	Yes	1			x			0	2	5	4	3	0	8	6	0.57	0.43
Chinese Crested	Yes	1		x				1	0	0	0	8	5	9	5	0.64	0.36
Chiuahuah	Yes	1			x			2	3	4	4	6	10	12	8	0.60	0.40
Dachshound	Yes	1		x				0	0	1	1	0	4	1	5	0.17	0.83
Dachshound	Yes	1			x			2	0	2	3	1	2	5	9	0.36	0.64
Dachshound	Yes	1			x			0	0	3	0	5	4	8	4	0.67	0.33
Frenchie	Yes		2		x			3	4	5	3	6	8	14	15	0.48	0.52
Frenchie	Yes	1					x	2	1	4	2	6	4	12	10	0.55	0.45
Frenchie	Yes	1				x		0	0	1	2	2	2	3	4	0.43	0.57
Frenchie	Yes	1			x			3	2	4	1	8	5	15	8	0.65	0.35
Frenchie	Yes	1			x			0	0	1	0	3	5	4	5	0.44	0.56
Frenchie	Yes	1			x			4	0	0	0	2	6	6	11	0.35	0.65
Frenchie	Yes		2			x		2	0	3	4	9	2	14	6	0.70	0.30
German Sherpard	Yes	1			x			3	0	2	2	3	0	8	2	0.80	0.20
German Shorthaired Pointer	Yes	1			x			6	9	3	7	1	7	10	23	0.30	0.70
German Shorthaired Pointer	Yes	1		x				0	2	3	4	2	4	5	12	0.29	0.71
Golden Doodle	Yes	1				x		0	3	2	1	6	1	8	10	0.44	0.56
Golden Doodle	Yes		2			x		0	3	2	4	0	3	2	10	0.17	0.83
Golden Doodle	Yes	1			x			2	1	2	3	3	1	7	5	0.58	0.42
Golden Doodle	Yes		2		x			2	3	3	4	0	4	5	11	0.31	0.69
Golden Retriever	Yes	1			x			0	6	3	7	9	8	12	11	0.52	0.48
Golden Retriever	Yes	1			x			3	0	2	1	6	0	11	1	0.92	0.08
Golden Retriever	Yes		2			x		1	4	2	1	3	2	6	7	0.46	0.54
Golden Retriever	Yes		2	x				0	2	0	1	0	8	0	11	0.00	1.00
Golden Retriever	Yes		2			x		2	0	1	0	2	5	5	12	0.29	0.71
Great Dane	Yes	1			x			3	1	1	3	4	1	8	5	0.62	0.38
Husky	Yes	1			x			2	2	4	6	3	4	9	12	0.43	0.57
Husky	Yes	1				x		2	3	4	1	2	1	8	10	0.44	0.56
Husky	Yes	1			x			2	2	4	6	3	4	9	12	0.43	0.57
Husky	No	1			x			3	1	2	3	5	1	10	5	0.67	0.33
Husky	No	1				x		2	3	4	1	2	1	8	11	0.42	0.58
Husky	Yes	1			x			1	1	1	1	5	0	7	2	0.78	0.22
Lab	Yes		2			x		3	6	1	2	0	5	4	13	0.24	0.76
Lab	Yes		2		x			5	2	2	4	3	3	10	9	0.53	0.47
Lab	Yes	1				x		0	4	2	1	6	0	8	12	0.40	0.60
Lab	Yes	1			x			2	0	3	2	3	0	8	2	0.80	0.20
Maltese	Yes		2		x			3	4	0	4	2	3	5	11	0.31	0.69

Maltese	Yes		2		x			1	2	3	5	6	8	10	15	0.40	0.60
Maltipoo	Yes	1		x				1	0	2	1	2	2	5	8	0.38	0.62
Mastiff	Yes		2	x				0	2	1	1	1	3	2	6	0.25	0.75
Pitbull	Yes		2		x			2	4	0	1	1	3	3	10	0.23	0.77
Pitbull	Yes	1					x	2	5	7	4	6	1	15	10	0.60	0.40
Pitbull	Yes		2		x			0	2	3	1	3	4	6	7	0.46	0.54
Pitbull	No	1			x			1	2	6	2	2	1	9	5	0.64	0.36
Pitbull	Yes	1				x		2	2	2	3	5	2	9	11	0.45	0.55
Pitbull	Yes	1					x	3	0	1	2	1	1	5	3	0.63	0.38
Puggle	Yes	1						0	3	2	2	3	0	5	5	0.50	0.50
Samoyed	Yes	1			x			3	1	2	3	5	1	10	5	0.67	0.33
Samoyed	No	1			x			1	1	1	1	5	0	7	2	0.78	0.22
Shitzu	Yes	1			x			0	0	0	1	4	5	4	6	0.40	0.60
Shitzu	Yes		2		x			2	5	0	0	0	7	2	12	0.14	0.86
Vishla	Yes	1		x				4	0	1	3	4	0	9	3	0.75	0.25
Unknown	Yes	1			x			1	0	3	2	4	0	8	12	0.40	0.60
Unknown	Yes		2			x		3	0	2	5	0	6	5	11	0.31	0.69
Unknown	Yes	1			x			1	2	5	3	2	7	8	12	0.40	0.60
Boxer mix	Yes		2		x			1	2	3	4	4	4	8	10	0.44	0.56
Cattle mix	Yes	1				x		4	1	2	1	1	4	7	6	0.54	0.46
Chiuahuah mix	Yes	1			x			1	2	1	1	2	3	4	6	0.40	0.60
Dachshound/Lab	Yes	1		x				1	1	2	1	3	0	6	2	0.75	0.25
pitbull mix	Yes		2	x				0	3	1	3	0	4	1	10	0.09	0.91
Pitbull/Lab	Yes		2		x			1	2	3	1	2	5	6	8	0.43	0.57
Pointer/Lab	Yes		2			x		0	2	2	4	3	4	5	12	0.29	0.71
Sharpee mix	Yes	1				x		3	0	0	0	9	1	12	10	0.55	0.45
Sharpee mix	Yes	1				x		4	0	2	3	3	1	9	4	0.69	0.31
Terrier mix	Yes	1			x			0	0	2	2	6	2	8	11	0.42	0.58
Terrier mix	Yes	1			x			0	1	3	3	2	7	5	11	0.31	0.69

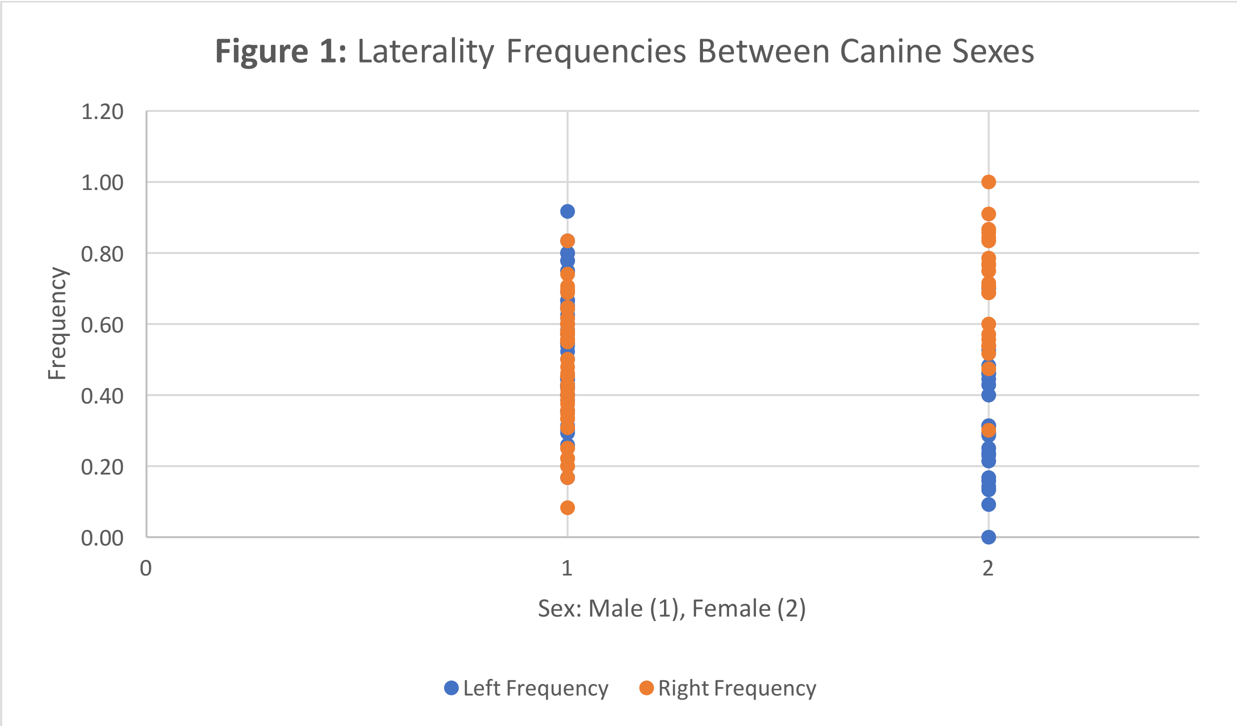


Figure 1: Laterality Frequencies Between Canine Sexes
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Frequency
0
1
2
Sex: Male (1), Female (2)
Left Frequency
Right Frequency

Figure 1a. Left Frequencies

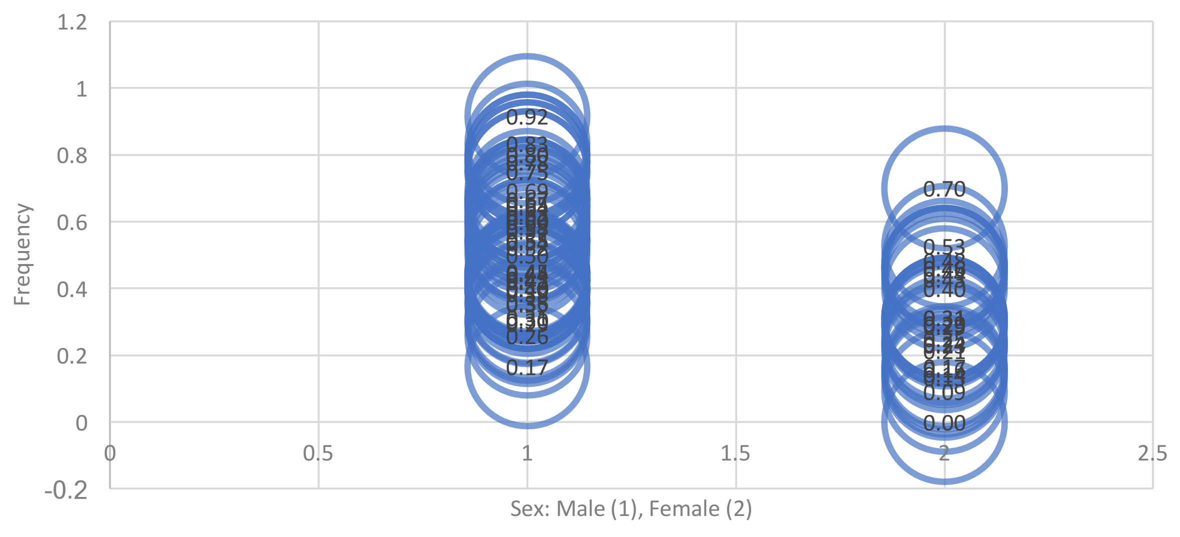
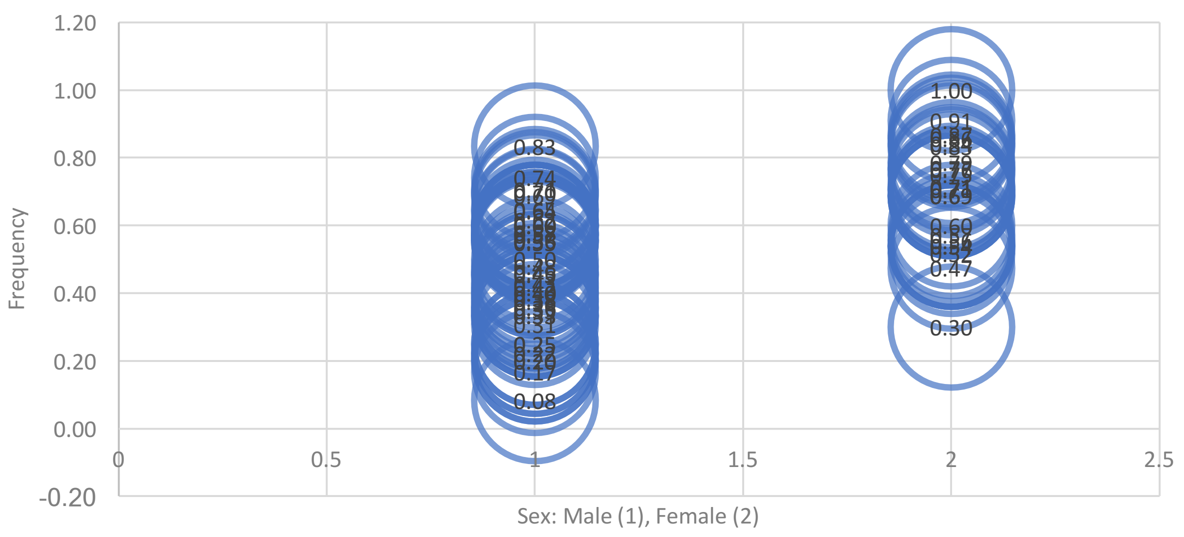


Figure 1b. Right Frequency



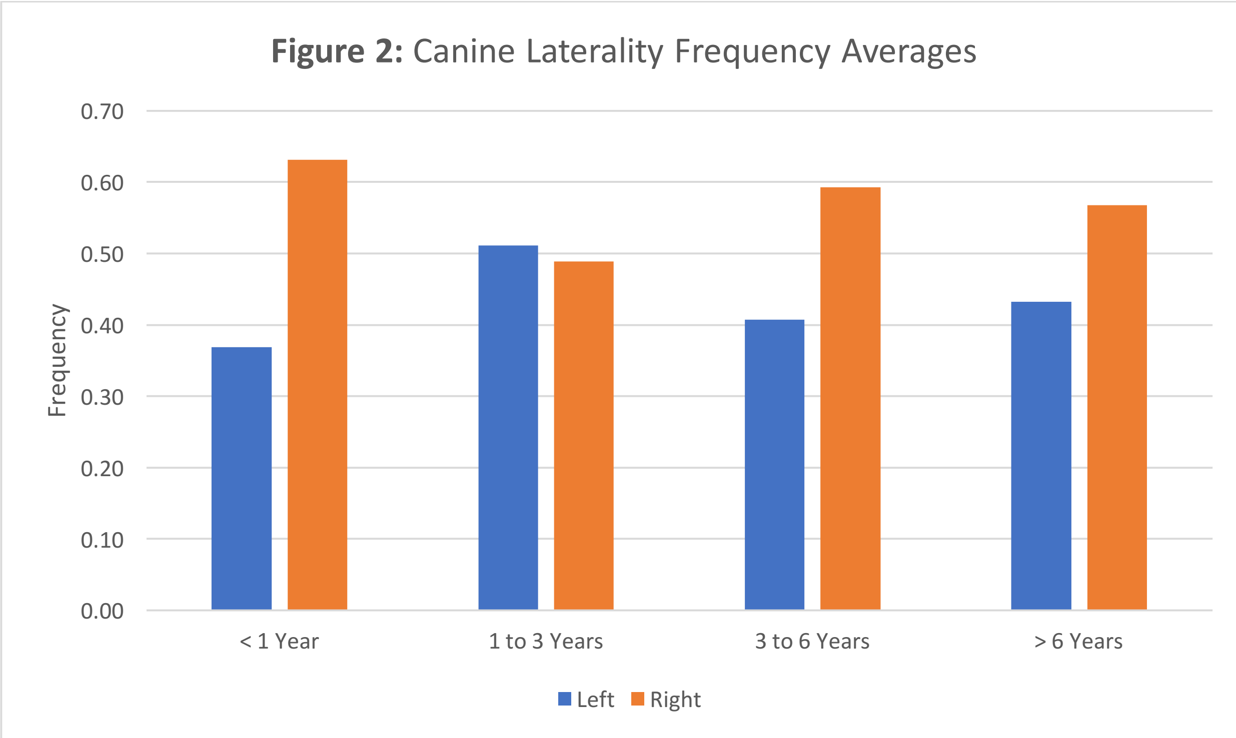


Figure 2: Canine Laterality Frequency Averages
Frequency
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
< 1 Year
1 to 3 Years
3 to 6 Years
> 6 Years
Left
Right

Table 2.

<u>Parameters</u>	<u>Paw Preference</u>	
	Left Paw	***Right Paw***
Male	25 Subjects (52.1%)	22 Subjects (45.8%)
Female	2 Subjects (8%)	23 Subjects (92%)
<1 years	3 Subjects (33.3%)	6 Subjects (66.7%)
1-3 years	17 Subjects (43.6%)	22 Subjects (56.4%)
3-6 years	4 Subjects (22.2%)	14 Subjects (77.8%)
>6 years	3 Subjects (60%)	2 Subjects (40%)
Sit to Stand	113 Subjects (45.2%)	137 Subjects (54.8%)
Kong	161 Subjects (47.5%)	178 Subjects (52.5%)
Tape	236 Subjects (48.8%)	248 Subjects (51.2%)

Discussion

My study focused on the lateralization of *Canis familiaris* in comparison to other vertebrate lateralization, specifically on preferential pawedness. The modern dog, *Canis familiaris*, comes in all shapes and sizes but for thousands of years has served one main purpose, as man's best friend. This bond, established between human and dog, dates back tens of thousands of years, and established a relationship of mutualism, both giving and receiving care from one another. Archeological, genetic and genomic studies provided insight into how the modern dog evolved from their ancestral origin dating back to the gray wolf. Evolution is defined changes in heritable characteristics over time, giving rise to biodiversity in all living things. These changes over time are driven by mutation, alteration of a gene; natural selection, a varied path resulting in survival of the current fittest; and genetic drift, random variation of genotypic frequencies in small populations. However, through thousands of years of domestication, *Canis familiaris* has been further sculpted to fit individual needs whether it be cosmetic, accessory, working or protection purposes. Sharing the same newly adapted environment as humans with similar medical care makes them models for genetic research. Given that humans, *Homo sapiens sapiens*, are just a small notch on the evolutionary tree, it should be of no surprise the extraordinary similarities we have to all vertebrates (and even invertebrates). Ongoing research of early development, molecular biology, genetics and genomics bridges gaps in what is known about the animal kingdom.

This study of *Canis familiaris* was to determine statistical evidence of apparent trends in lateralization. 73 domestic dogs were studied using a series of tasks to determine their preferred paw focusing on specific parameters such as gender and age. Figure 1, 1a and 1b above are graphs of the canine population which focused on average laterality frequencies of all tasks performed. Male calculations, showed 25 out of the 48 of the male population (52.1%) used their left paw and 22 out of 48 of the male population (45.8%) used their right paw. Female calculations showed 8% of the tested population preferred the left paw (2 out of 25) and 92% (23 out of 25) of the population preferred the right. Furthermore, female right paw frequencies were between 0.30 and 1.00 (Figure 1b) and left paw frequencies were between 0.00 and 0.70 (Figure 1a). Male right paw frequencies were between 0.08 and 0.83 (figure 1b) and left paw frequencies were between 0.17 and 0.92 (Figure 1a).

Figure 2 shows the variation of frequencies between age groups. The tested population was divided into four groups: Ages less than one year, one to three years, three to six years and ages greater than six. There was a total of 9 dogs under one year of age; three (33.3%) preferred the left paw and six (66.7%) preferred the right. 39 dogs were between the ages one and three years of age; 17 (43.6%) preferred the left paw and 22 (56.4%) preferred the right. 18 dogs were between the ages three and six years of age; four (22.2%) preferred the left paw and 14 (77.8%) preferred the right. Lastly, a total of 5 dogs were over the age of six; 3 (60%) preferred the left paw and 2 (40%) preferred the right.

Conclusion

This study of *Canis familiaris* was to determine statistical evidence of apparent trends in lateralization such as preferred handedness in humans. 73 domestic dogs were studied using a series of tasks to determine their preferred paw focusing on specific parameters such as gender and age. Dogs and their owners were approached through a local apartment community and surrounding parks. Owners were given information about this study, provided consent and demographic backgrounds of their dog, including age, weight, sex, breed and reproductive status. Tests performed include a tape test, where a tally was taken of each paw used to try and remove the tape; the Kong ® test, where there was a tally of the leading paw used to stabilize the toy when retrieving the treat; and lastly, the advancement of paw/limb from the seated position.

Most dogs did not show clear paw preference during tasks, appearing to be ambidextrous, although in some cases, data shows usage of one paw more than the other. Observations based on gender showed possible evidence of preferred pawedness in females. 25 out of the observed 73 dogs were female and calculations showed 92% (23 out of 25) of the population preferred the right paw. The other 8% of the female population preferred the left, which accounted for 2 out of 25. Other studies suggest that lateralization is variable between sexes, where females show a right-paw preference and males show a left-paw preference (Siniscalchi, d'Ingeo, and Quaranta, 2017). In this study, males did not show evidence of a preferred paw (see Figures 1, 1a and 1b).

This study also focused on laterality based on age. In humans, "asymmetries in movement patterns have been observed as early as the tenth week of gestation," (Kinsbourne, 2009). Although, in contrast, the hypothesis was *Canis familiaris* would show a trend in development where ages below one year would show symmetry, or an even frequency of left and right pawedness opposed to those who were older, who would have a higher frequency of left or right pawedness, showing asymmetry. The population was divided into four age groups: Ages less than one year, one to three years, three to six years and ages greater than six. Although, shown in Figure 2, the data shows higher frequencies of right paw usage in ages less than one year, three to six years and ages greater than six, and an almost even frequency of left and right paw usage between the ages of one to three. Therefore, data did not support the hypothesis in this study.

Additional observations were made based on specified tasks and breed cohorts but no conclusive evidence was determined. Through thousands of generations of inbreeding and manipulation, true evidence could be difficult to obtain. However, the continued study of laterality in all species is important to better understand the intricacies of life today and still provides information in conjunction with neural, cognitive and emotional studies. To elaborate: Neural asymmetry shows that the function of the nervous system in behaviorally simple organisms is distributed across two domains: regulation of internal environment and the control of behavior oriented in space. However, more sophisticated vertebrates feature higher mental function shown in areas such as communication, memory and problem solving (Kinsbourne, 2009). It is important to fill in these gaps to better help understand how enhance these skills. Furthermore, studies of tail wagging in *Canis familiaris* have been connected with cognition which could possibly lead to improvements in canine welfare and the relationships between dog and human. Which means, understanding lateralization could give us more insight on their emotional state (Siniscalchi, d'Ingeo, and Quaranta, 2017).

In conclusion, it was difficult to determine whether or not the data suggested true laterality in *Canis familiaris*. Positive results were found in females, where an extremely high frequency of right preferential pawedness was obvious and also consistent with other studies.

However, newer research questions pawedness in dogs, suggesting that paw preference is task-specific and not to be considered true pawedness (Wells, Hepper, Milligan and Barnard, 2018).

Acknowledgements

These past two years at SUNY Purchase College has presented me with many challenges as an adult, full-time working student taking on heavy course loads of upper-level science classes. So, it is without surprise that my first and strongest thank you goes to my senior project sponsor and all the other professors that have impacted me over the past few years. These professors have guided, encouraged, pushed, and corrected me. Thanks to them, this experience will never be forgotten and was well worth all the hard work and sacrifice. A very, very special thank you to my sponsor, Dr. Lee Ehrman, and also to Dr. Mark Jonas, Dr. James Daly and last but most certainly not least, the Biology department's chair, Dr. Jan Factor. I would also like to extend a thank you to my immediate family, Sara and Ira Brody, for their ongoing and unconditional support as I continue to push forward toward my goals. And also to Rhoda and George Shapiro for their endless, loving, encouragement throughout my treacherous educational past and bright future. Finally, I would like to thank my biggest inspiration for returning to school, my father, Abel Mingola. I wish he were here to see this chapter in my life finally completed.

Bibliography

Dobzhansky, T. 1973. Nothing in Biology Makes Sense except in the Light of Evolution. *The American Biology Teacher.* **35**:125-129.

Dotson, M., and Hyatt, E.M. 2007. Understanding dog-human companionship. *Journal of Business Research.* **61**:457-466. https://www.sciencedirect.com/science/article/pii/S0148296307002214 Accessed March 30, 2018.

Hecht, J. 2013. Find the Gaps. *New Scientist*. **217.** http://ezproxy.purchase.edu:2072/ehost/detail/detail?vid=4&sid=0f3eb760-8b03-45a6-86f5-f0791ddcf16c%40pdc-v-sessmgr03&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d#AN=85606326&db=rzh Accessed April 4, 2018.

Kinsbourne, M. 2009. Development of Cerebral Lateralization in Children. *Handbook of Clinical Child Neurophyschology.* 47-66. https://www.researchgate.net/publication/227128421_Development_of_Cerebral_Lateralization_in_Children Accessed April 3, 2019.

Nowack, E.C.M., and Melkonian, M. 2010. Endosymbiotic association within protists. *Philosophical Transactions of the Royal Society B.* **365**:699-712. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2817226/ Accessed April 4, 2018.

O'Neill, D.G., and Packer, M.A. 2016. The first canine behavior and genetics conference: Summary and recommendations for future directions in canine behavioral science. *Journal of Veterinary Behavior*. **16**:6-12.

https://ezproxy.purchase.edu:2976/S1558787816300016/1-s2.0-S1558787816300016-main.pdf?_tid=2eac1358-df35-4d68-bf40-b78a3d9d6f6c&acdnat=1523629438_2f128c51b716cd62c749b60d22f2cb5e Accessed March 30, 2018.

Schaafsma, S.M., Riedstra, B.J., Pfannkuche, K.A., Bouma, A., and Groothuis, T.G.G. 2008. Epigenesis of behavioural lateralization in humans and other animals. *Philosophical Transactions of the Royal Society*. **364**: 915-927. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2666084/pdf/rstb20080244.pdf Accessed April 3, 2018.

Siniscalchi, M., d'Ingeo, S., Fornelli, S., and Quaranta, A. 2016. Relationship between visuospatial attention and paw preference in dogs. *Scientific Reports*. ***6****:1-8*. https://www.nature.com/articles/srep31682 Accessed April 3, 2018.

Siniscalchi, M., d'Ingeo, S., and Quaranta, A. 2017. Lateralized functions in the dog brain. *Symmetry*. *1-12*. http://www.mdpi.com/2073-8994/9/5/71/htm Accessed April 3, 2018.

Thalmann, O., Shapiro, B., Cui, P., Schuenemann, V.J., Sawyer, S.K., Greenfield, D. L., Germonpré, M. B., Sablin, M. V., López-Giráldez, F., Domingo-Roura, X., Napierala, H., Uerpmann, H-P., Loponte, D. M., Acosta, A. A., Giemsch, L., Schmitz, R. W., Worthington, B., Buikstra, J. E., Druzhkova, A., Graphodatsky, A. S., Ovodov, N. D., Wahlberg, N., Freedman, A. H., Schweizer, R. M., Koepfli, K.-P., Leonard, J. A., Meyer, M., Krause, J., Pääbo, S., Green, R. E., and Wayne, R. K. 2013. Complete mitochondrial genomes of ancient canids suggest a

European origin of domestic dogs. *Science.* **342**:871-874.
https://ezproxy.purchase.edu:2269/pubmed/24233726 Accessed March 30, 2018.

Uppsala University. 2015. Evolution of Darwin's finches and their beaks. *ScienceDaily*.
https://www.sciencedaily.com/releases/2015/02/150211141238.htm Accessed May 6, 2018.

Wells, D.L., Hepper, P.G., Milligan, A.D.S., Barnard, S. 2018. Stability of motor bias in the domestic dog, *Canis familiaris*. *Behavioural Processes*. **149**: 1-7.
https://www.sciencedirect.com/science/article/abs/pii/S0376635717304837 Accessed April 3, 2019.