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Comparison of Visual and DNA Breed Identification of Dogs and Inter-Observer Reliability

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Abstract Until the recent advent of DNA analysis of breed composition, identification of dogs of unknown parentage was done visually, and visual identification is still the most common method of breed identification. We were interested in how often visual identification of dogs by people, assumed to be knowledgeable about dogs, matched DNA breed identification and how often these people agreed with each other (inter-observer reliability). Over 900 participants who engaged in dog related professions and activities viewed one-minute, color video-clips of 20 dogs of unknown parentage and were asked to identify the dogs' predominant breeds. For 14 of the dogs, fewer than 50% of the respondents visually identified breeds of dogs that matched DNA identification. Agreement among respondents was also very poor. Krippendorf's alpha was used to examine the reliability of the most predominant breed (selected across all dogs identified as mixed breeds) for all respondents, yielding alpha=0.23. For only 7 of the 20 dogs was there agreement among more than 50% of the respondents regarding the most predominant breed of a mixed breed and in 3 of these cases the most commonly agreed upon visual identification was not identified by DNA analysis.

Keywords Inter-observer Reliability of Dog Breed Identification, Visual and DNA Identification of Mixed Breed Dogs

1. Introduction

The breed by which a dog is identified has important implications and ramifications. Breed identification is used in public health journals, veterinary medical records, lost and found notices, licensing documents and animal shelter descriptions. How a dog is identified also influences how people interpret a dog's behavior. World-wide, public and private regulations and restrictions have been enacted that regulate dog ownership, euthanasia, availability of liability insurance, and access to housing. These rules may specify specific breeds, mixes of these breeds, or any dog that resembles these breeds. We were interested in how often visual identification of dogs by people assumed to be knowledgeable about dogs matched DNA breed identification, and how often these people agreed with each other (inter-observer reliability).

Estimates of the prevalence of specific breeds of dogs that engage in injurious behaviors appear in numerous published articles related to public health, canine behavior, andveterinary medicine. Data concerning dog breeds, particularly pertaining to human injuries, are frequently tabulated from newspaper accountsor retrospective reviews of hospital and animal control records[1-10]. Sometimes dogs in these reports are identified by owners according to what they believe is the most predominant breed of their dog[4],[6],[9] or from information entered in veterinary medical records based on the staffs' assessments[9],[11]. Generally, published reports supply no data on who identifiedthe dogs' breeds[12]. Adding to the confusion, data are often published in a manner that combines dogs identified as purebreds with purebred crosses, e.g. the German Shepherd Dogand German Shepherd cross would bedepicted as German Shepherds[4],[7]; all dogs identified as pit bull breeds and pit bull hybrids would be categorized as a pit bull[10]. Although such publications may include cautionary statements that thebreed identifications were unverified, potentiallyinaccurate, and that data on the numbers and breeds of dogs in the source population were unknown[3-7], breed frequencies are still included in the publications.

With the intention of providing public safety, regional and national governments have attempted to regulate dog ownership, how a dog is maintained, and impose euthanasia policies based on the perceived breed composition of a dog, be it a purebred or mixed breed[12-20]. Insurance premiums and housing restrictions are also based on a dog's

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breed composition[8],[19],[20]. Until the recent advent of DNA analysis of breed composition[21-25] identification of dogs of unknown parentage was done visually, and visual identification is still the most common method of breed identification, even by law enforcement, animal care and control agencies, and veterinarians[19],[20],[26]. As examples, see the animal control ordinances of Prince George's County Maryland, Denver Colorado, and Victoria, Melbourne Australia[27-29].

Our personal observations of discrepancies among people who attempt to visually identify the breed composition of dogs prompted this study. We were interested in how often visual identification by people assumed to be knowledgeable about dogs was in agreement with DNA identification, and how often people agreed with each other (inter-observer reliability). We felt this was important because of the potential ramifications of misclassification of dog breeds in published databases which drive public and private policies as well as people's perceptions of the behavior of individual dogs.

People who engage in professions or services that involve dogs are one source of identification of dogs of unknown parentage. They are in a position to provide their opinion to owners about the possible breed or predominant breed of their dogs. They may also directly assign a breed identity to dogs and enter their opinions on office forms and/or records. Either way, these identifications have the potential to be entered into national databases which are used for prevalence statistics on dogs' breeds.

2. Methods

The protocol for the study was approved by the Institutional Review Board and Institutional Animal Care and Use Committee of the Western University of Health Sciences, Pomona California.

2.1. Source of Participants

The participants were recruited by contacting organizations involved in dog-related activities, such as veterinary medical groups, animal control/sheltering agencies, dog clubs, and regional and national conferences related to veterinary medicine and dog-related activities. Permission was requested to administer an anonymous, voluntary, dog breed identification quiz and survey (collectively referred to as the questionnaire), followed by an educational presentation. It was asked that the participants be at least 18 years old and able to understand and write English. At the time of the presentations, the participants were also informed that participation was anonymous, voluntary, could be discontinued at any time and that their responses were part of a research project. These sessions were administered in person, by either the Principle Investigator or a trained research assistant, at 30 locations in the following states: Arizona, California, Colorado, Louisiana, Massachusetts, Missouri, Ohio, Tennessee, Texas, Utah, and Washington. Many of these sites were at regional or national meetings with participants from several states.

2.2. Source of Dogs

Twenty privately-owned dogs of unknown parentage were selected for the study from a pool of dogs that had been volunteered by their owners to participate in dog breed identification studies[26]. Forty of 50 volunteered dogs met the entrance criteria of being mature enough to have fully erupted canine teeth, having been obtained from a shelter, rescue, animal control or similar adoption agency, and being available on a specific day to be videotaped and have blood drawn. The 40 dogs were assigned to one of 4 weight ranges: ≤20 lbs. (9.07 kg), 21-40 lbs. (9.52-18.14 kg), 41-60 lbs.(18.60- 27.22 kg), and > 60 lbs. (27.22 kg). Five dogs were randomly selected from each weight range and entered into the study. The study dogs included 7 castrated males, 12 spayed females and 1 intact female. They had been adopted from 17 different locations in North America but currently residing in Southern California. Figure 1 depicts each study dog against a white screen with a black-lined grid of one-foot squares. The pictures are freezed frames from the videotapes that were shown to the participants. Detailed descriptions of each dog are provided Table 1.

2.3. DNA Analysis

Two ml samples of heparinized blood from each dog were immediately refrigerated and sent on the same day on cold packs by overnight shipment to MARS VETERINARY™ Lincoln, Nebraska for DNA analysis. There were 130 American Kennel Club (AKC) registered purebreds in their database and the laboratory reported "an average of 84% accuracy in the first-generation crossbred dogs of known parentage"[22],[23]. Contributions of ancestral breeds less than 12.5% were not reported. The laboratory had in their database the AKC breed American Staffordshire Terrier but not any breeds identified as Pit Bull or American Pit Bull Terrier. Because of the common ancestry, historical reciprocal registrations, and similar morphology, we used visual identifications of American Staffordshire Terrier, Pit Bull, and American Pit Bull Terrier as matches to the DNA identification of American Staffordshire Terrier. For several years, the American Kennel Club (AKC) allowed dogs to be registered as Staffordshire Terriers (later changing the name to American Staffordshire Terrier) if the dogs were already registered as American Pit Bull Terriers in the United Kennel Club (UKC) or American Dog Breeders Association (ADBA) registries. Until 2010, the UKC permitted registration of AKC and ADBA dogs as American Pit Bull Terriers. AKC registered American Staffordshire Terriers are still allowed to be registered as American Pit Bull Terriers in the ADBA[30-33].We are not, however, suggesting that they are identical.

For each dog, the breeds identified by DNA were classified as Major or Minor based on the relative

percentage of the breed represented in that dog. Breeds reported at the highest percentage of DNA in a dog were classified as Major; breeds reported at lower percentages in that dog were classified as Minor. A dog could have more than one Major DNA breed identification, e.g., three breeds each represented at 25%. If only one breed was detected in a dog by DNA analysis, that breed was considered the Major breed, even if it was only 12.5% of the dog's composition. Results of the DNA analyses of breed identification of each dog are in Table 1. None of the dogs were reported to be purebreds by DNA analysis.

2.4. Administration of Study Questionnaire

Administration of the questionnaire and following educational program took about 55 minutes. The participants were shown one minute, color video-clips of each of the 20 dogs which were allowed to move about in front of a white screen with a black-lined grid of one-foot squares. Full bilateral and frontal views and a close up of the head were depicted. The participants were told the age, weight, and sex of each dog as they viewed the videos. After each video-clip, the respondents were given as much time as they requested to write in their answers. The video-clips were not re-shown. The respondents were required to generate their answers. They did not have access to resource materials and were asked not to solicit breed identifications fromeach other. In our experience, most dogs are often visually identified quickly as either a single breed or a single breed mix, generally without consulting resources. The video-clips were always shown the same order (Dog 1-20) which was the order that the owners, at their convenience, had brought their dogs to be videotaped.

2.5. The Survey and Quiz Questions

Participants were asked to indicate: their current and past professional activities; if they now or ever have been asked what breed a dog appears to be; if their opinions have ever been used to assign possible breed identities for the purposeof records (e.g. shelters, medical, licensing, other businesses); and personal descriptive questions such as their age and sex, how many dogs they have, and if they have ever competed in any dog related activities, such as showing, agility, hunting, etc.

For each dog, the respondents were asked:

-"Do you think this dog is probably a purebred?"

□ YES □ NO

-"If YES, (you think this IS probably a purebred) What breed do you think it is?"

-"If NO, (you do NOT think this a purebred) What do you think is the most predominant breed?"

-"What do you think is the second most predominant breed. (If you are unable to determine a second breed, write "Mix" here. Otherwise, name a breed.)"

In this article, identification as "not a purebred" is used synonymously with "mixed-breed". The answer to the most predominant breed of a Mixed Breed is referred to as the Primary Visual Identification (PVI) and an answer to the second most predominant breed is referred to as the Secondary Visual Identification (SVI).

Figure 1. Pictures of the 20 study dogs against a backdrop of 1 foot square grid of 1 foot squares

Table 1. Descriptions of the 20 Study Dogs and Percent of Major and Minor Breeds Identified by DNA Analysis

Dog ID	Sex	Approximate Age	Weight – lbs. (kg)	Major Breeds Identified by DNA	Minor Breeds Identified by DNA
1	FS	3 Years	51 (23.1)	American Staffordshire Terrier**; Saint Bernard**	Chinese Shar-Pei*
2	FS	9 Years	31 (14.1)	American Eskimo Dog**; Golden Retriever**; Nova Scotia Duck-Tolling Retriever**; Rottweiler**	
3	MC	5 Years	60 (14.1)	English Springer Spaniel**; German Wirehaired Pointer**	
4	MC	2.5 Years	26 (11.8)	Lhasa Apso**	Australian Cattle Dog*; Bischon Frise*; Italian Greyhound*; Pekingese*; Shih Tzu*
5	FS	12 Years	51 (23.1)	Australian Shepherd Dog*; Chow Chow*; Dalmatian*; German Shepherd*; Siberian Husky*	
6	FS	5 Years	54 (24.5)	Chow Chow*; Dachshund*; Nova Scotia Duck -Tolling Retriever*	
7	MC	10 Months	15 (6.8)	American Water Spaniel*; Black Russian Terrier*; Pomeranian*; Shih Tzu*; Tibetan Terrier*	
8	FS	2 Years	41 (18.6)	Chow Chow**; French Bull Dog**	Clumber Spaniel* Dalmatian*; Gordon Setter*; Great Dane*
9	FS	7 Years	66 (30)	Dalmatian**	Boxer*; Chow Chow*; Newfoundland*
10	MC	5.5 Years	10 (4.5)	Australian Shepherd Dog**; Pekingese**	
11	MC	3 Years	62 (28.1)	American Staffordshire Terrier**; German Shepherd Dog**	Bull Terrier* Chow Chow*
12	FS	1.5 Years	52 (23.6)	Australian Shepherd Dog*; Boxer*; Dachshund*; Dalmatian*; Glen of Imaal Terrier*	
13	MC	3.5 Years	79 (35.8)	Alaskan Malamute*	
14	FS	3.5 Years	74 (33.6)	German Shepherd Dog**; Standard Schnauzer**	English Setter*
15	FS	7 Years	70 (31.8)	Chow Chow*; Golden Retriever*; Gordon Setter*; Saint Bernard*	
16	F	5.5 Months	20 (9.1)	Australian Shepherd Dog*; Boxer*; Golden Retriever*	
17	FS	2 Years	18 (8.2)	Cavalier King Charles Spaniel*; Chihuahua*; Shih Tzu*	
18	FS	10 Months	13 (5.9)	Miniature Pinscher***;	Dachshund*
19	FS	12 Years	36 (16.3)	Border Collie**	Bassett Hound*; Cocker Spaniel*
20	MC	6 Years	21 (9.5)	Shih Tzu**	Cocker Spaniel*; Miniature Schnauzer*;Pekingese*

Percent of breed composition detected by DNA: *12.5%; **25%; *** 50% FS, female spay; MC, male castrate; FI, female intact.

Dogs of unknown parentage are generally designated by only one breed, e.g., Chow mix, German Shepherd mix[26]. We believe that when a dog is so identified, the assumption is that the named breed is the most predominant breed in the dog's ancestry. Therefore, we wanted to know how often our respondents' visual identification of the most predominant breed matched breeds identified at the highest percentage by DNA analysis. Secondarily, we were interested in whether or not a breed visually identified as the most predominant matched any breed identified by DNA, regardless of the percentage of DNA composition. And thirdly, we examined whether any visual identification, either the first or second breed identified, matched any percentage of DNA breed identified.

3. Results

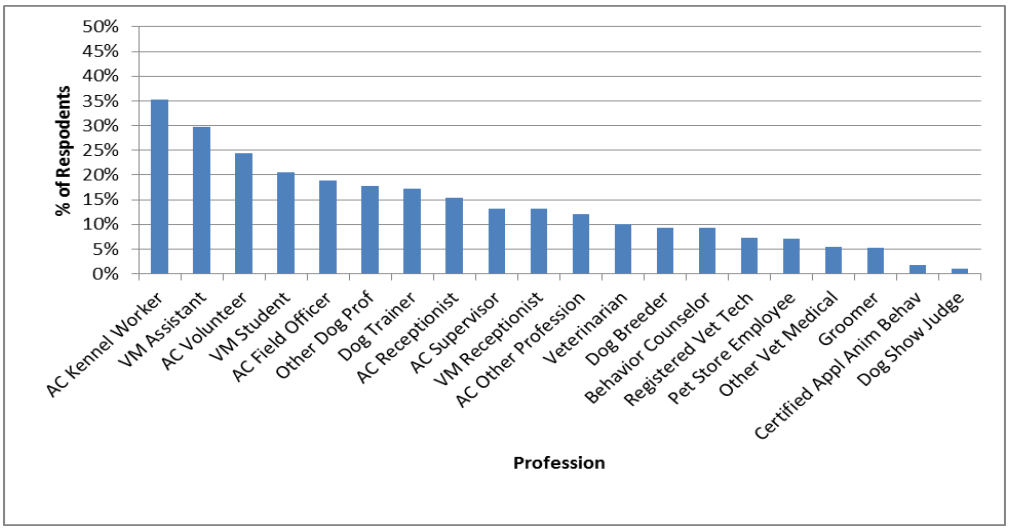
Nine hundred eighty six people completed all or part of a questionnaire. The questionnaires of 63 respondents were excluded from analysis for the following reasons: did not answer or answered "No" to the question "Are you now, or have you ever been asked what breed a dog appears to be."; did not provide any information regarding their professions; or indicated they were less than 18 years old. Respondents were asked to indicate on the questionnaire if a specific dog was theirs or if they knew a dog's DNA composition; data pertaining to these dogs were not included in the study, although data provided by the respondent pertaining to other dogs were included. All responses pertaining to a specific dog were tabulated, unless the answer was illegible.

3.1. Profile of Respondents

Most respondents indicated involvement in more than one dog-related profession/service, either sequentially or simultaneously.The majority of respondents were or had been in animal control/sheltering and/or veterinary medical fields, see Figure 2.

People in animal control and veterinary medical fields were significantly more likely to have their opinions of a dog's breed used for record keeping purposes than not have their opinions so used ($p <= 0.001$). Volunteers, veterinary medical students, and behavior counselors were significantly

less likely to assign breed identities for record keeping (p= 0.002) rather than have their opinions used for record keeping. See Table 2.



Most respondents engaged in multiple occupations, either sequentially or simultaneously, therefore the cumulative percent is over 100 %. AC, Animal care and control or similar agency; VM, Veterinary Medical; Vet Tech, Veterinary Technician; Certified Appl Anim Behav, Certified Applied Animal Behaviorist

Figure 2. Percent of 923 respondents engaged in each profession/service activity

Table 2. Comparison of Percent of Respondents That Assigned and Did Not Assign Breed Identities for Record Keeping Purposes Within Each Profession/Service

	All Respondents	GROUP A	GROUP B	Chi-Square*	*p*
Current or Past Profession		Opinions Used to Assign Breed Identities in Records	Opinions NOT used to Assign Breed Identities in Records	(comparing Group A to B)	
Kennel Worker	35.2%	40.7%	17.6%	39.295**	<0.001
Supervisor	13.2%	16.7%	2.3%	30.403**	<0.001
Field Officer	19.0%	24.1%	2.7%	49.907**	<0.001
Receptionist/Office Assistant (Animal Care)	15.4%	18.2%	6.3%	18.281**	<0.001
Volunteer	24.5%	22.1%	32.1%	9.176**	0.002
Other Animal Care	12.1%	14.1%	5.9%	10.653**	0.001
Veterinarian	10.1%	11.3%	6.3%	4.488**	0.034
Receptionist/Office Assistant (Vet Office)	13.2%	13.7%	11.8%	0.535	0.465
Registered Veterinary Technician (RVT)	7.3%	9.1%	1.4%	15.033**	<0.001
Veterinary Assistant	29.7%	31.2%	24.9%	3.206	0.073
Veterinary Student	20.6%	18.2%	28.1%	9.916**	0.002
Other Vet Medical	5.5%	5.1%	6.8%	0.886	0.346
Trainer	17.2%	17.0%	18.1%	0.155	0.693
Groomer	5.3%	5.3%	5.4%	0.008	0.927
Pet Store Employee	7.2%	7.7%	5.4%	1.296	0.255
Behavior Counselor	9.2%	10.8%	4.1%	9.170**	0.002
Certified Applied Animal Behaviorist	1.7%	1.7%	1.8%	0.01	0.920
Dog Show Judge	1.1%	1.0%	1.4%	0.204	0.652
Dog Breeder	9.3%	7.4%	15.4%	12.659**	<0.001
Other Dog-Related Profession	17.8%	16.5%	21.7%	3.105	0.078
Total Sample Size	923	702	221		

Notes: *statistical tests in this table compare the percentage of respondents selecting a profession as a current or past profession (shown) to those that did not (not shown) by respondent segment. **significant at the p=0.05 level

Chi-Square tests, adjusted for all pairwise comparisons using the Bonferroni correction, were used to compare two segments of the respondents: Group A (n=702) those whose opinions, currently or in the past, were used for record keeping purposes (documentation) and Group B (n=221)those whose opinions were not so used. There were no significant statistical differences between Groups A and B regarding: the respondents' gender, if they participated in other dog related activities (such as dog shows, agility, hunting, etc.), or if they lived with or owned dogs ($p>0.05$). A t-test indicated no significant difference regarding age. See appendix for comparisons of participants' personal demographics.

3.2. Comparison of Visual Identification and DNA Breed Identification

The DNA analysis indicated none of the dogs were purebreds and most respondents identified the study dogs as mixed breeds. See Table 3. However, 7 of the 20 dogs were visually identified as probably purebreds by ten percent or more (range 10% - 25.4%) of the respondents. An average of 9.2 % (1701/18408) of the responses were "yes" to the question "Do you think this dog is probably a purebred?".

A positive match between visual and DNA identification occurred if (1) the respondent indicated that the dog was not a purebred and (2) also specified a breed identified by DNA.The following were NOT considered matched responses:

if the dog was visually identified as a purebred (even if the breed identified was one identified as part of the dog's composition by DNA analysis) OR if the dog was visually identified as not a purebred but identified as breed that was not reported by DNA analysis.

For each dog, the percent of respondents whose visual identification matched the DNA identification was calculated by dividing the number of matched responses for a dog (numerator) by the sum of matched and unmatched responses (denominator). For each dog, we looked at how often visual and DNA identification matched at the three progressively less stringent levels:

- Level 1: Respondent indicated that the dog was NOT a Purebred AND the most predominant breed (Primary Visual Identification/ PVI) matched at least one of the Major DNA Identifications for that dog.
- Level 2: Respondent indicated that the dog was NOT a Purebred AND the PVI matched any DNA Identification (Major or Minor) of that dog.
- Level 3: Respondent indicated that the dog was NOT a Purebred AND EITHER PVI or SVI (second most predominant breed) visual identification matched any DNA Identification of that dog.

There were few significant statistical differences between those who had their opinions used for record keeping purposes (Group A) and those who did not have their opinionsso used (Group B) regarding the frequency with which visual and DNA identification matching occurred at any of the 3 levels of matching stringency. See appendix for comparisons of the two groups at the 3 levels of matching stringency. We concluded the few differences between groups A and B to be of no practical significance and combined the groups for subsequent analysis.

Table 3. Number and Percent of Respondents That Answered "Yes," They Thought the Dog was a Purebred

Dog ID	Yes/Total	Percent
1	18/918	2.0%
2	63/917	6.9%
3	92/917	10.0%
4	17/919	1.8%
5	120/920	13.0%`
6	36/920	3.9%
7	79/919	8.6%
8	75/922	8.1%
9	234/921	25.4%
10	134/919	14.6%
11	116/922	12.6%
12	81/922	8.8%
13	71/921	7.7%
14	36/922	3.9%
15	59/921	6.4%
16	32/922	3.5%
17	48/921	5.2%
18	172/922	18.7%
19	25/919	2.7%
20	193/919	21.0%
Overall	1703/18403	9.2%

DNA analysis indicated that none of the dogs were purebred

The combined data showed that as the stringency levels for matching deceased, the percentage of matches increased. However the agreement between visual and DNA identification was low at all three levels, see Table 4. There were no matches of visual and DNA identifications at Level 1 for five dogs, no matches for four dogs at Level 2, and at Level 3, the most liberal criteria, no matches for one dog. For 8 dogs, fewer than 5% of the respondents' visual identifications matched any DNA identification at Level 3; for only 6 dogs did more than 50% of the respondents' visual identifications match any DNA identification.

3.3. Inter-Observer Reliability of Visual Identification of Most Predominant Breed of Dogs Identified as Mixed Breeds

Agreement among the respondents was also very poor, see Table 5 and see appendix. There was agreement among more than 50% of the respondents regarding the most predominant breed of a mixed breed for only 7 dogs and for 3 of these dogs the visual identification did not match any (either major or minor) DNA breed identification

Krippendorff's alpha was used to examine the reliability of the most commonly visually identified predominant breed (selected across all dogs identified as mixed breeds) for all respondents, yielding alpha=0.23 which is generally considered to represent low levels of inter-observer reliability[34],[35].The data was treated dichotomously, the respondents either provided the same answer (breed) or not.

Table 4. Percent and Number of Respondents Whose Visual Identification Matched DNA Breed Identification for Each Dog at 3 Levels of Matching Stringency

	LEVEL 1: PVI Matched a Major DNA Breed Identification		LEVEL 2: PVI Matched Any DNA Breed Identification		LEVEL 3: PVI or SVI Matched Any DNA Breed Identification	
Dog ID	Percent	Yes / Total	Percent	Yes / Total	Percent	Yes / Total
1*	33.20%	290/873	35.70%	312/873	62.80%	550/876
2	43.00%	369/859	43.00%	369/859	53.10%	457/860
3	7.20%	62/863	7.20%	62/863	11.90%	103/863
4	0.10%	1/852	9.40%	80/852	12.40%	106/852
5	72.90%	653/896	72.90%	653/896	81.90%	734/896
6	0.00%	0/856	0.00%	0/856	0.10%	1/856
7	1.90%	17/872	1.90%	17/872	4.60%	40/872
8	0.00%	0/862	0.60%	5/862	1.90%	16/862
9	70.40%	639/908	70.50%	640/908	73.00%	664/909
10	0.00%	0/884	0.00%	0/884	0.10%	1/884
11*	53.70%	471/877	53.70%	471/877	64.50%	566/877
12	0.10%	1/831	0.10%	1/831	0.40%	3/831
13	0.00%	0/859	0.00%	0/859	0.00%	0/859
14	29.50%	260/880	29.50%	260/880	47.50%	418/880
15	0.20%	2/890	0.20%	2/890	0.70%	6/890
16	27.10%	218/805	27.10%	218/805	31.80%	256/805
17	56.60%	496/877	56.60%	496/877	75.30%	661/878
18	0.00%	0/869	0.00%	0/869	0.10%	1/869
19	10.80%	89/821	11.00%	90/821	14.60%	120/821
20	33.30%	283/849	38.20%	324/849	44.90%	381/849

PVI, Primary Visual Identification; SVI, Secondary Visual Identification; Any DNA Breed Identification, Major or Minor Breed relative representation in a dog. *American Staffordshire Terrier (AST), Pit Bull and Pit Bull Terrier visual identifications were considered matches to DNA analysis breed identification of AST. Percentages in bold indicate over 50% of the visual identifications matched DNA identifications.

Table 5. Breed of Dog Most Often Visually Identified as Primary (PVI) in Dogs Also Visually Identified as a Mixed Breed

Dog ID	Breed Identified by Greatest Percentage of Respondents	Percent Identifying That Breed	Number of Respondents
1	Labrador Retriever	39.9%	855
2	Golden Retriever	39.3%	796
3	Border Collie	45.7%	771
4	Pug	37.0%	835
5	**GERMAN SHEPHERD DOG**	**59.1%**	777
6	German Shorthaired Pointer	33.0%	820
7	**CORGI**	**56.7%**	793
8	**PIT BULL/AST* (39.5%/12.1%)**	**51.6%**	787
9	**DALMATIAN**	**94.8%**	674
10	Yorkshire Terrier	16.6%	751
11	**GERMAN SHEPHERD DOG**	**61.2%**	762
12	Labrador Retriever	16.4%	750
13	German Shorthaired Pointer	14.4%	790
14	German Shepherd Dog	30.8%	844
15	**LABRADOR RETRIEVER**	**86.9%**	831
16	Australian Shepherd Dog	23.9%	774
17	**CHIHUAHUA**	**55.5%**	831
18	Cairn Terrier	23.5%	697
19	Collie	14.6%	796
20	Shih Tzu	43.2%	657

*AST, American Staffordshire Terrier. PVI=Most Predominant Visual Identification. Breeds in UPPERCASE and bold indicate over 50% of the respondents were in agreement

4. Discussion

This study reveals a wide disparity between DNA and visual identification of the predominant breeds comprising a dog. It also indicates a low level of agreement among people regarding breed composition. Those of us in the animal care services have always remarked on the differences of opinions regarding what breed a dog is but few are aware of how little agreement there is or how often one's own opinion could be wrong.

The wide range of responses by the participants are compatible with research and theories pertaining to judgments of probability based on partial information[36-42]. Identification of the breed composition of a dog requires recognition and recall, both of which are influenced by a multitude of variables, such as perception, knowledge base, memory, recent or salient experiences with the subject matter, and cognitive abilities involving categorization, sorting, matching and recombination of features.

Identification is affected by what features (stimuli) a person notices and how much weight the person attributes to those features. For example, some people may attend to the hair coat and color pattern of a dog, while others focus on size, shape of head, or whether or not the tail is curled. The ease with which people notice a feature enhances recall and increases the weight that is placed on that feature. For example, so much significance is placed on any black pigmentation of a dog's tongue that, regardless of the morphology of the dog, it is usually identified as a Chow Chow or Chow mix. The frequency with which people are exposed to the names of specific breeds of dogs and their perception of the population of specific breeds will also influence prediction. Interestingly, the literature indicates that well educated professionals are as susceptible to judgmental biases as are the lay public[36],[37],[43],[44].

The low percentage of agreement between visual and DNA identification may be partially explained by perception biases. However, DNA identification of the proportion of purebred breeds in mixed breed dogs is not perfect either, nor do the laboratories that provide such analyses claim to be infallible. The average accuracy of identification of the breeds in an individual dog can be expected to decrease as the heterogeneity of its ancestors increases. Canine Heritage™ states that their accuracy of identification of known registered purebred dogs is 99%[45]. Wisdom Panel™ currently reports a 90% average accuracy of identification ofF1 crosses of known registered purebred dogs[46].

After completing the quiz, the DNA results were revealed to the participants. However, it was not until we showed them pictures of the F1 and F2 crosses of registered purebred dogs[47] did the participants begin to realize that mixed breed dogs may not look like theirpurebred parents or grandparents. The mixed breeds bore little, if any resemblance, to their purebred parents or grandparents. Crosses of purebred dogs (particularly beyond the firstgeneration) can result in unique combinations and a collage of features.In fact, the pictures of Scott and Fuller's dogs looked more like breeds other than their immediate ancestors. Many current breeds were derived by crossing existing breeds or by selecting for morphological variations within a breed until a "new" breed was established[25],[30]. It actually shouldn't be surprising that visual identification of mixed breeds does not always agree with DNA based breed identification. A recent genetic study in dogs determined that very few regions of the canine genome encode morphological traits associated with breed-defining physical traits[48]. Dogs have on the order of 20,000 to 25,000 genes and fewer than 1% of the dog's genes control the external morphological features associated with specific breeds of dogs, such as ear shape and size, whether the ears are floppy, length of the legs, length of the coat, coat color and shape of the head and length of muzzle. A dog could genetically be 50%a German Shepherd Dog and lack the genomic regions responsible for the German ShepherdDog size, coat color, muzzle length and ear properties.

Even after Scott and Fuller's pictures were shown, there was reluctance to consider that the DNA results might be correct. This is compatible with observations that people often adhere to their beliefs even when data is present that contradicts their beliefs and the confidence with which people adhere to these beliefs may actually increase when presented with contradictory data[36],[44],[49].

Misidentification of a dog's breed composition is not a trivial matter. How a dog is identified can affect many people and dogs. Dog ownership is common worldwide[50-53].In the United States approximately 40% of households have at least one dog,there is an increasing trend to obtain dogs from animal shelters/humane societies, and ownership of mixed breeds is increasing compared to purebreds[50],[51].

4.1. Limitations of the Study

It is possible that the breeds of these 20 dogs in this study are unusually difficult to identify visually. Similar studies should be conducted with other samples of dogs and by other researchers.

5. Conclusions

The disparities between visual and DNA identification of the breed composition of dogs and the low agreement among people who identify dogs raise questions concerning the accuracy of databases which supply demographic data on dog breeds, as well as the justification and ability to implement laws and private restrictions pertaining to dogs based on breed composition.

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APPENDIX

Table 6. Comparisons of Respondents' Personal Demographics by Whether or Not Their Opinions Were Used to Assign Dog Breed

			GROUP A n=702	GROUP B n=221	Stat Test Result	
		All Respondents	Opinions Used to Assign Breed Identities in Records	Opinions NOT Used to Assign Breed Identities in Records	(comparing Group A to B)	*p*
Respondent Gender	Female	75.7%	74.2%	80.8%	χ^2=3.687	0.055
	Male	24.3%	25.8%	19.2%		
	N	875	677	198	N/A	
Respondent Age	Mean	37.6	37.3	38.9	t=-1.427	0.155
	Median	35.0	35.0	38.0		
	Standard Deviation	12.5	12.0	14.0		
	N	826	642	184		
Participation in Dog-Related Activities	Yes	30.3%	29.8%	31.7%	χ^2=0.279	0.597
	No	69.7%	70.2%	68.3%		
	N	909	701	208	N/A	N/A
Own/Reside with Dogs	Yes	82.9%	83.8%	79.8%	χ^2=1.806	0.179
	No	17.1%	16.2%	20.2%	N/A	N/A
	N	890	687	203	N/A	N/A

χ2=Chi-Square. t=Student t-test. N= Number answering this question. Not all participants answered each of the questions

Table 7. Comparison and Percent of Level 1 Matches for Groups A and B

	GROUP A Opinions Used for Records	GROUP B Opinions NOT Used for Records		
Dog ID	% (n / N)	% (n / N)	Chi-Square	*p*
1*	33% (224 / 679)	33.2% (66 / 199)	0.002	0.963
2	40.8% (273 / 669)	48.7% (96 / 197)	3.907**	0.048
3	7.4% (50 / 674)	6.2% (12 / 193)	0.326	0.568
4	0% (0 / 664)	0.5% (1 / 202)	Fisher's Exact Test=0.233	
5	72.8% (500 / 687)	73.2% (153 / 209)	0.015	0.904
6	0% (0 / 669)	0% (0 / 192)	NA	
7	2.4% (16 / 671)	0.5% (1 / 205)	Fisher's Exact Test=0.142	
8	0% (0 / 672)	0% (0 / 194)	NA	
9	69.8% (484 / 693)	72.1% (155 / 215)	0.399	0.528
10	0% (0 / 679)	0% (0 / 210)	NA	
11*	51.6% (350 / 678)	59.6% (121 / 203)	4.002**	0.045
12	0.2% (1 / 653)	0% (0 / 192)	Fisher's Exact Test=1.000	
13	0% (0 / 671)	0% (0 / 196)	NA	
14	28.2% (192 / 680)	33.2% (68 / 205)	1.849	0.174
15	0.3% (2 / 684)	0% (0 / 210)	Fisher's Exact Test=1.000	
16	27.5% (176 / 640)	23.1% (42 / 182)	1.423	0.233
17	54.6% (371 / 680)	61.6% (125 / 203)	3.127	0.077
18	0% (0 / 671)	0% (0 / 203)	NA	
19	11.9% (77 / 647)	6.3% (12 / 190)	4.822**	0.028
20	32.4% (213 / 657)	35.9% (70 / 195)	0.82	0.365

*American Staffordshire Terrier (AST), Pit Bull and Pit Bull Terrier visual identifications were considered matches to DNA analysis breed identification of AST n/N number of matches for that dog/Number of respondents that answered the question for that dog.**significant at $p < 0.05$ level

Table 8. Comparison and Percent of Level 2 Matches for Groups A and B

	GROUP A Opinions Used for Records	**GROUP B Opinions NOT Used for Records**		
Dog ID	% (n / N)	% (n / N)	Chi -Square	*p*
1*	35.9% (244 / 679)	34.2% (68 / 199)	0.209	0.647
2	40.8% (273 / 669)	48.7% (96 / 197)	3.907**	0.048
3	7.4% (50 / 674)	6.2% (12 / 193)	0.326	0.568
4	10.1% (67 / 664)	6.4% (13 / 202)	2.467	0.116
5	72.8% (500 / 687)	73.2% (153 / 209)	0.015	0.904
6	0% (0 / 669)	0% (0 / 192)	NA	
7	2.4% (16 / 671)	0.5% (1 / 205)	Fisher's Exact Test=0.142	
8	0.6% (4 / 672)	0.5% (1 / 194)	Fisher's Exact Test=1.000	
9	70% (485 / 693)	72.1% (155 / 215)	0.35	0.554
10	0% (0 / 679)	0% (0 / 210)	NA	
11*	51.6% (350 / 678)	59.6% (121 / 203)	4.002**	0.045
12	0.2% (1 / 653)	0% (0 / 192)	0.294	0.587
13	0% (0 / 671)	0% (0 / 196)	NA	
14	28.2% (192 / 680)	33.2% (68 / 205)	1.849	0.174
15	0.3% (2 / 684)	0% (0 / 210)	Fisher's Exact Test=1.000	
16	27.5% (176 / 640)	23.1% (42 / 182)	1.423	0.233
17	54.6% (371 / 680)	61.6% (125 / 203)	3.127	0.077
18	0% (0 / 671)	0% (0 / 203)	NA	
19	12.1% (78 / 647)	6.3% (12 / 190)	5.042	0.025
20	37.7% (248 / 657)	39% (76 / 195)	0.096	0.757

*American Staffordshire Terrier (AST), Pit Bull and Pit Bull Terrier visual identifications were considered matches to DNA analysis breed identification of AST n/N number of matches for that dog/Number of respondents that answered the question for that dog. **significant at $p < 0.05$ level

Table 9. Comparison and Percent of Level 3 Matches for Groups A and B

	GROUP A Opinions Used for Records	**GROUP B Opinions NOT Used for Records**		
Dog ID	**% (n / N)**	**% (n / N)**	**Chi -Square**	***p***
1*	62.5% (425 / 680)	62.2% (125 / 201)	0.006	
2	52.2% (350 / 670)	54.3% (107 / 197)	0.263	
3	12.5% (84 / 674)	9.8% (19 / 193)	0.983	
4	13.4% (89 / 664)	8.4% (17 / 202)	3.587	
5	82.8% (569 / 687)	78.9% (165 / 209)	1.626	
6	0.1% (1 / 669)	0% (0 / 192)	Fisher's Exact Test=1.000	
7	5.4% (36 / 671)	2% (4 / 205)	Fisher's Exact Test=0.054	
8	2.1% (14 / 672)	1% (2 / 194)	Fisher's Exact Test=0.545	
9	72.6% (503 / 693)	74.5% (161 / 216)	0.319	
10	0.1% (1 / 679)	0% (0 / 210)	Fisher's Exact Test=1.000	
11*	63% (427 / 678)	68.5% (139 / 203)	2.052	
12	0.5% (3 / 653)	0% (0 / 192)	Fisher's Exact Test=1.000	
13	0% (0 / 671)	0% (0 / 196)	NA	
14	45.4% (309 / 680)	53.2% (109 / 205)	3.776	
15	0.6% (4 / 684)	1% (2 / 210)	Fisher's Exact Test=0.630	
16	31.9% (204 / 640)	28.6% (52 / 182)	0.721	
17	73.7% (502 / 681)	78.3% (159 / 203)	1.762	
18	0.1% (1 / 671)	0% (0 / 203)	Fisher's Exact Test=0.630	
19	15.9% (103 / 647)	8.9% (17 / 190)	5.813	
20	44.1% (290 / 657)	46.7% (91 / 195)	0.388	

*American Staffordshire Terrier (AST), Pit Bull and Pit Bull Terrier visual identifications were considered matches to DNA analysis breed identification of AST .n/N number of matches for that dog/Number of respondents that answered the question for that dog. **significant at $p < 0.05$ level

Table 10. The Top 5 Breeds/Types Most Often Visually Identified as "The Most Predominant" in Each of the 20 Dogs Identified as Mixed Breeds and Corresponding DNA Breed Identification

Dog ID	The five most frequently visually identified breeds/type and % of respondents indicating that breed	N	Major Breeds Identified by DNA	Minor Breeds identified by DNA
1	Labrador Retriever 39.9% ; Pit Bull 27.4% ; Rhodesian Ridgeback 9.6% ; **American Staffordshire Terrier** 6.5% ; **Chinese Shar-Pei** 2.6%	855	**American Staffordshire Terrier** ** ; Saint Bernard **	**Chinese Shar-Pei** *
2	**Golden Retriever** 39.3% ; Labrador Retriever 7.3% ; Border Collie 7% ; Australian Shepherd 6.8% ; **American Eskimo Dog** 6.5%	796	Rottweiler ** ; **American Eskimo Dog** ** ; **Golden Retriever** ** ; Nova Scotia Duck-Tolling Retriever **	
3	Border Collie 45.7% ; Flat-Coated Retriever 8.9% ; Australian Shepherd 8% ; **English Springer Spaniel**, **Springer Spaniel** 8% ; Labrador Retriever 5.7%	771	**English Springer Spaniel** ** ; German Wirehaired Pointer **	
4	Pug 37% ; Corgi 12.9% ; **Pekingese** 9.1% ; Chihuahua 8.5% ; Beagle 6.1%	835	Lhasa Apso **	Bischon Frise * ; Australian Cattle Dog * ; Italian Greyhound * ; **Pekingese** * ; Shih Tzu *
5	**German Shepherd Dog** 59.1% ; **Siberian Husky** 24.5% ; Shepherd, Sheepdog 4.5% ; Akita 4.2% ; Australian Cattle Dog, Blue, Red, Queensland Heeler 2.7%	777	**German Shepherd Dog*** ; Australian Shepherd Dog * ; **Siberian Husky** * ; Chow Chow * ; Dalmatian *	
6	German Shorthaired Pointer 33% ; Pointer, English Pointer 18.4% ; Australian Cattle Dog, Blue, Red, Queensland Heeler 11.1% ; Labrador Retriever 4.9% ; Catahoula Leopard Dog 3.3%	820	Chow Chow * ; Dachshund * ; Nova Scotia Duck-Tolling Retriever *	
7	Corgi 56.7% ; Chihuahua 14.1% ; German Shepherd Dog 4.3% ; Pembroke Welsh Corgi 3.5% ; Shetland Sheepdog 2.4%	793	American Water Spaniel*; Black Russian Terrier*; Pomeranian * ; Tibetan Terrier * ; Shih Tzu * ;	
8	Pit Bull 39.5% ; Labrador Retriever 13.7% ; American Staffordshire Terrier 12.1% ; Bulldog 9% ; Jack Russell Terrier 5.3%	787	Chow Chow **; French Bull Dog **	Clumber Spaniel *; Dalmatian*; Gordon Setter * ; Great Dane *
9	**Dalmatian** 94.8% ; Pit Bull 1.8% ; Labrador Retriever 0.7% ; Australian Cattle Dog, Blue, Red, Queensland Heeler 0.4% ; Pointer, English Pointer 0.4%	674	**Dalmatian** **	Boxer * ; Chow Chow * ; New Foundland *
10	Yorkshire Terrier 16.6% ; Schnauzer 10.4% ; Terrier 9.6% ; Chihuahua 9.1% ; Cairn Terrier 8.9%	751	Australian Shepherd Dog **; Pekingese ** ;	
11	**German Shepherd Dog** 61.2% ; Belgian Malinois 7.3% ; Shepherd, Sheepdog 7.1% ; Akita 2.8% ; Belgian Sheepdog, Belgian Shepherd 2.8%	762	American Staffordshire Terrier **; **German Shepherd Dog** **	Bull Terrier*; Chow Chow*
12	Labrador Retriever 16.4% ; Pharaoh Hound 15.7% ; German Shepherd Dog 12.8% ; Basenji 8.9% ; Greyhound 6.9%	750	Australian Shepherd Dog *; Boxer * ; Dachshund*; Dalmatian*;Glen of Imaal Terrier *	
13	German Shorthaired Pointer 14.4% ; Pointer, English Pointer 13.3% ; American Foxhound, Foxhound 8.6% ; Coonhound 7.5% ; Treeing Walker Coonhound, Treeing Walker Hound 6.7%	790	Alaskan Malamute *	
14	**German Shepherd Dog** 30.8% ; Australian Shepherd 27.1% ; Australian Cattle Dog, Blue, Red, Queensland Heeler 8.4% ; Catahoula Leopard Dog 7.6% ; Rottweiler 5.2%	844	**German Shepherd Dog** **; Standard Schnauzer **	English Setter*
15	Labrador Retriever 86.9% ; Rottweiler 5.1% ; Border Collie 1.4% ; German Shepherd Dog 1.2% ; Australian Shepherd 0.8%	831	Chow Chow*; Golden Retriever *; Gordon Setter*; St. Bernard*	
16	**Australian Shepherd** 23.9% ; Cocker Spaniel 8.5% ; Border Collie 8.3% ; Spaniel 7.5% ; German Shepherd Dog 5%	774	**Australian Shepherd Dog** * ; Boxer *; Golden Retriever*	
17	**Chihuahua** 55.5% ; Beagle 9.1% ; Jack Russel Terrier 7.6% ; **Cavalier King Charles Spaniel** 4.2% ; Pekingese 4%	831	**Cavalier King Charles Spaniel** * ; **Chihuahua** *; Shih Tzu*	
18	Cairn Terrier 23.5% ; Terrier 11% ; Wire Fox Terrier 9.3% ; West Highland White Terrier 8.5% ; Yorkshire Terrier 6.7%	697	Miniature Pinscher ***	Dachshund *

19	Collie 14.6% ; Beagle 13.9% ; German Shepherd Dog 11.4% ; **Border Collie** 11.2% ; Smooth Coated Collie 9%	796	**Border Collie** **	Bassett Hound *; Cocker Spaniel *
20	**Shih Tzu** 43.2% ; Lhasa Apso 25.9% ; **Cocker Spaniel** 4.4% ; Maltese 3.2% ; Terrier 3%	657	**Shih Tzu** **	**Cocker Spaniel** * ; Miniature Schnauzer*; Pekingese *

* 12.5% breed composition by DNA. ** 25% breed composition by DNA. *** 50% breed composition by DNA
For calculations of inter-observer reliability of each dog, only the answers of respondents who indicated that the dog was not a purebred and committed to what they thought was the most predominant breed in that dog were used

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