Canine Research

Intraspecific killing in dogs: Predation behavior or aggression? A study of aggressors, victims, possible causes, and motivations

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ARTICLE INFO

ABSTRACT

In the Netherlands, dogs may be seized by the police when they have killed or seriously wounded another dog. Police reports on these incidents reveal that some dogs attack vigorously and fast, without warning. In the veterinary behavior clinic at Utrecht University, these types of attacks were earlier recognized in referred dogs, leading to a set of diagnostic criteria for "dog-killing aggression" to distinguish from ritualized intraspecific aggressive patterns. To understand these vigorous types of attacks better, details from police reports and behavior test results of a group of 128 seized dogs and data gathered during behavioral anamneses of 151 referred dogs in a clinical setting were systematically analyzed to identify (1) the type of aggressors, (2) the victims, and (3) the possible factors underlying this intraspecific killing, including motivations. With respect to the aggressors, the population of referred dogs included a broad range of breeds with no breed outstanding. In contrast, in the seized dog population, 56% of the dog-killing dogs were of the American Staffordshire/pit bull terrier type. This difference might reflect owner characteristics with one group being less intended to ask for help in case of problem behavior or it could suggest a genetic, predisposition to react with dog-killing aggression in contact with other dogs or there may be combination of elements. These data, however, are not a proof of a genetic predisposition. In the seized dog population, 83% of victims were small-sized dogs of different breed types. The analysis of the anamnesis of the referred dogs, and voluntary remarks by owners of the seized dogs, revealed that the most frequently mentioned event precipitating this form of vigorous fast attack without warning was having been attacked by a dog somewhat earlier in life (36/24% of these referred dogs). Other, less frequently mentioned precipitating factors were insufficient socialization to other types of dogs during the primary socialization period (21/14% of these referred dogs) or showing a general tendency to prey on other species (9/6% of these referred dogs). The data suggest that for a number of dogs, aggression, rather than predation, was the underlying motivation, but that certain characteristics of the attacks strongly resemble predatory behavior. For the large majority of seized dogs, no information was available on their life history, which limits conclusions regarding causal factors. Therefore, predation cannot be excluded for some dogs. Dog-killing dogs may limit themselves to attacking the type of dog they had unpleasant experiences with before (specialists), or they may generalize their aggressive behaviors to several types of prospective victims (generalists) as found in the data. The consequence of these findings is that getting prior information on the type of victims and the precise details of the attacks are of utmost importance for testing, diagnostics, and making risk assessments. We plead for preventing escalating dog-dog aggression by management and training intervention and not letting the dogs "sort out their conflicts by fighting" because having been attacked by another dog may be an initiating event in some dogs to develop dog-killing aggression.

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Introduction

Millions of dogs live in close proximity to humans, but in a relatively small number of cases, this leads to dog bite–related human fatalities (Patronek et al., 2013; Mora et al., 2018). It is

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known that dogs also kill other dogs, but numbers for dog bite–related dog fatalities have not been reported in the literature. Studies revealed that around 22%-47% of dogs display aggression toward unfamiliar dogs (Blackwell et al., 2008; Casey et al., 2013; Wormald et al., 2016). Hence, many dogs may be involved in intraspecific/interdog aggression. The large majority of intraspecific dog conflicts are resolved through showing ritualized signals, which include affiliative and agonistic submissions and threatening behaviors (Fox et al., 1969; Cafazzo, et al., 2010; Overall, 2013; van der Borg et al., 2015; Trisko and Smuts, 2015; Bonnani et al., 2017). Aggression between dogs may result in wounds. Although standardized records are missing, only a small minority of dogs would be expected to get severely wounded (Mouro et al., 2010), and death as a consequence of an intraspecific attack will be rare.

In the veterinary behavior clinic of Utrecht University, The Netherlands, a referral clinic for companion animals with behavioral issues, it was observed that aggressors that inflicted serious or even lethal wounds attacked their victims in a specific way that does not fall into the range of normal intraspecific aggression (as described in the ethograms of intraspecific aggression for social communication, e.g., Schenkel, 1967; Overall, 2013; van der Borg et al., 2015, Bonanni et al., 2017). Characteristics frequently mentioned by owners during anamneses were collated and were used to formulate a set of criteria to assess whether or not such a referred dog could be labeled with "dog-killing aggression," as we have called this type of aggression in daily jargon for the high risk of the death of a victim. These characteristics included the following: (1) the attack was silent (no vocalizations) and fast, (2) the attack could start a large distance from the victim, (3) fixation on the victim occurred before the dog started the run toward the victim, (4) raising the hackles and a short period of stalking may occur before attacking, (5) no prior threatening behaviors such as barking, growling, baring the teeth preceded the (attempted) attack, (6) the dog could not be distracted before and during the attack, (7) the aggressor bit the victim immediately and forcefully, (8) the victim was often shaken vigorously, (9) owners (or bystanders) experienced great difficulties in getting the aggressor to release the victim, (10) the bite-related wounds were severe (torn skin, perforations of intestines, broken limb, or the victim died or was euthanized because of the seriousness of its wounds), and finally, (11) aggressors did not react to submissive, deferential, or avoidance behaviors of their victim. Moreover, some owners reported that their dogs scanned the environment for potential victims while being walked and were highly aroused. The level of arousal has been reported to increase when another dog came in view or when dog and owner approached a place where dogs could be expected, which suggests anticipation. Victims were usually said to be of the same sex as the aggressor and remarkably, some aggressors appeared only to react to specific (types of) dogs in the aforementioned way of attacking.

Some of the above-listed behavioral characteristics correspond to those labeled by O'Farrell (1986) as characteristic for "predatory aggression"' and by Dehasse (2002) as characteristic for "secondary hyperaggression." The latter describes specific dog attacks without "intimidation" (= threat), direct and unforeseen, or that the threat may occur during or after the attack, but not before. The aggressor is unresponsive with respect to submissive behavior from the part of its victim. Askew (1996) wrote the anthropomorphic but interesting sentence that it appears that some dogs simply "do not like" certain kinds of dogs and that these dogs tend to behave offensively aggressive toward these typical victims, under any circumstances. Owners of such dogs often identify specific incidents in their dog's past after which such behaviors started. Dogs that were attacked may display aggressive behavior to their former attacker and also to other dogs that look similar. Lindsey (2002) states that in these

situations, owners often report a single unanticipated attack as the sole precipitating event preceding the aggressive behavior of their dog that seemed to attack preemptively.

These anecdotical descriptions match the characteristics we deduced from the anamneses of our patients, which seem to suggest a more predatory motivation behind "dog-killing aggression" than normal intraspecific aggression. In many species, the neurophysiological and ethological basis of predatory behavior is generally considered to be different from that of intraspecific aggression (Weinshenker and Siegel, 2002; Haller, 2013; Tulogdi et al., 2015). Predatory behavior is usually defined as being directed and restricted to animals of other species than the attacker (Lorenz, 1966; Tulogdi et al., 2015). It involves a sequence of behaviors described by O'Heare (2007): orienting, fixating, stalking, followed by chasing, grab bite, kill bite, dissect, and consume. Chávez and Opazo (2012) described a case of a German shepherd dog, which together with other dogs in the household, attacked humans, dogs, cats, rabbits, and hens. They concluded that this dog showed predatory behavior, based on criteria as described by Overall (2013, p. 209).

Predatory behavior (also described as proactive, instrumental aggression; Siegel and Victoroff, 2009) is characterized by a goal-directed and purposeful attack in the absence of sympathetic arousal (Weinshenkel and Siegel, 2002). The pattern differs from normal intraspecific attack behavior in its neural regulation (Kaada, 1967; Siegel and Brutus, 1990; Siegel et al., 1999; Tulogdi et al., 2010). In cats, mutual inhibition between these two types of attacking behavior has been reported (Cheu and Siegel, 1998; Gregg and Siegel, 2001). Whereas with predatory behavior, the attacker is silent, sympathetic arousal is limited, and threatening communication is absent; intraspecific aggression (also named affective aggression) is characterized by emotional expressions, such as threatening vocalizations, postures, and attacking movements in response to provocations. The level of autonomic activation in affective aggression is high (Siegel et al., 1999).

Because "dog-killing aggression" includes behaviors that resembles many of the characteristics of predatory behavior rather than some level of what is considered normal intraspecific aggression (i.e., species-specific threatening behaviors, which might lead to lunges with inhibited snaps or bites shown in an appropriate context [Schenkel, 1967; van der Borg et al., 2015, Bonanni et al., 2017]), two main questions arise: first, what causal factors lead to the development of "dog-killing aggression"? Second, is "dog-killing aggression" predatory behavior or an "excessive" manifestation of intraspecific aggression as suggested by Haller (2013) and Tulogdi et al. (2015)?

In this article, we present a discussion with the help of an analysis of two data sources, investigating the behavioral characteristics of a large number of cases of "dog-killing dogs" with the aim to identify possible causal factors and to elucidate potential motivational backgrounds. We used (1) a data set with information derived from police reports and behavioral test results from dogs that were seized after having seriously injured or killed other dogs and (2) a data set from dogs that were referred to the secondary care veterinary behavior clinic at Utrecht University because of a history of attacking other dogs.

We hypothesized that three possible distinct motivational factors may be involved in dog-killing behavior. The first is based on Askew's (1996) proposal that attackers may start attacking other dogs shortly after the dog itself had been attacked. In case the dog specifically attacks dogs that are similar to its former attacker, the motivational factor is likely to be uninhibited, normal aggression rather than predatory behavior. Second, attackers lacking primary social exposure and socialization experiences with dogs other than their littermates and/or their dam may be prone to typically attack

dog breeds of a different morphological type. Fear or predation is expected to be the relevant underlying motivational factors. Third, for attackers that show a strong tendency for predatory behavior toward animals of other species besides and including dogs, a more general predatory motivation may be a more likely causal factor.

Methods and animals

Two data sets were used to provide insight into the causal factors underlying dog-killing behavior and whether dog-killing behavior is predatory behavior or an "excessive" manifestation of intraspecific aggression.

Data on seized dogs

Reports of 128 seized dogs, involved in incidents in which dogs were severely wounded or killed in public areas between 2010 and 2015, were included and analyzed in detail. All 128 dogs were housed in a shelter after confiscation. As required by Dutch regulations, these dogs were assessed for the present and future risk for society. This risk assessment contained a multimethod approach, including 5 types of sources of information: (1) assessors were licensed to use confidential police reports on biting incidents, which included more or less complete information of the biting dog's behavior and its victim(s); (2) information on the owners of the offending dogs and their behavior could be extracted from the police reports as well; (3) information from the veterinary health check of the seized dogs; (4) information on the dog's behavior at the shelter was retrieved from standardized records filled out by shelter staff, and (5) results of behavior tests. This information was collated to produce a risk assessment in a standardized format that included recommendations on preventing future risks with this dog.

Police reports included interviews with owners and other witnesses and provided information on the behavior of the seized dog and its victim(s), the sex, breed type of the aggressor and victim, and behavior of dog owners and of bystanders who tried to intervene in the attack. These interviews were reported in a question-answer format, reflecting verbatim answers by interviewees. In addition, damage caused by the dog was reported, often by means of an attached report by a veterinarian. We scrutinized these reports for all relevant information concerning the biting incident(s) and remarks on the history of the dog (when present), which was then entered in Excel files.

After at least a two-week period of habituation to the shelter's kennel and management situation, all seized dogs were tested using a standardized, modified (and substantially shortened) version of the shelter test, originally developed and validated by van der Borg et al. (1991). This test included a confrontation of the seized dog by two quietly behaved stimulus dogs of the same sex, one of a smaller size and one of the same or a larger size than the seized dog. During these tests, the seized dog was kept on a double leash of 2-meter length, connected to a fence or wall. The dog's familiar caretaker stood beside the dog during the tests, but just outside its range to avoid risk of redirected behavior. The stimulus dog was walked 3 times past the tested dog, just out of its range by an animal handler. During the third passage, the dog's caretaker tried to get and keep the attention of the seized dog, by calling it and, if the dog came over to the caretaker, to pet it or give it a treat, when safety permitted this. The aim of this procedure was to assess the degree of distractibility of the dog in the presence of a stimulus dog. All tests were recorded on video, and the footage was scored afterward on a standardized observation form with scaling scores (e.g., aggression, sociability, fearfulness, excitement, distractibility, and stress indicators).

A dog was labeled as displaying dog-killing aggression if it met one or more of the following criteria: (1) the dog was involved in killing or severely wounding a dog or dogs; (2) the police report described a sudden, fast, and unannounced attack, with immediate biting, and shaking of the victim and refusal of the attacker to let go of its victim; (3) the outcomes of the behavioral test provided a third set of criteria.

As a number of the characteristics listed in the introduction could not be observed with the behavioral test because of limitations in logistics (such as attacking from a large distance, biting and shaking of the victim and refusal of letting go off the victim, not responding to submissive behaviors, and the seriousness of wounds), a more limited number of criteria, derived from those listed in the introduction used in the behavior clinic, was used. These were no threatening behaviors such as growling, barking, or showing teeth preceding the attack; increased arousal, silent attempts to attack: strong, repeated approaches while intensely focusing on the stimulus dog and great difficulty or failure to distract the dog from the stimulus dog. The latter refers to characteristic 9: difficulty in getting the attacking dog to release its victim after biting. In addition, the opening of the mouth during attempts to attack the stimulus dog was used as an indication of the intention to bite (dogs reported as being severely wounded were usually rescued by people interfering in the incident, as evidenced by witness statements in police reports). When descriptions of the behavior of the aggressor in the police report suggested dog-killing behavior and this was confirmed in the behavioral test, the dog's behavior was labeled as "dog-killing aggression." The criterion to distinguish dog-killing aggression did not include having caused a fatality per sé but rather depended on behavior characteristics and test results that were concordant with those data from the police reports.

In the case of biting incidents involving a group of offending dogs, all the dogs that were seized were first tested individually, then as a group. In the group test, dogs were tethered at a safe distance from one another to prevent redirected aggression. A maximum group size of three dogs could be tested in this way. The test as described for individual dogs was replicated with the same caretaker present at both tests.

Data on dogs referred to the veterinary behavior clinic

Data of 151 cases of dogs with intraspecific aggression seen at the veterinary behavior clinic at Utrecht University between 2010 and 2015 were analyzed. This data set of referred dogs provided insight into aspects of the life history of dogs, an information category that was usually lacking in the data set of the seized dogs. During the consultation, a standardized behavioral anamnesis was conducted and the type of aggression was diagnosed on the basis of the description and video material (when present) provided by the owner. This anamnesis included questions regarding their dog being attacked in the past, and if so, by what breed type of dog and the date of the incident. Details of the breed, color type and sex of the victims, and the way the dog had attacked (or tried to attack) were also collected. Furthermore, information was obtained about whether the owner was able to intervene successfully by calling or correcting the dog during (the initial phase of) the attack, or was able to release the victim from its attacker. Owners stated often that they could not get the attention of their dog, when it was in "the mood." Further questions pertained to the early life environment, including breeder facilities, socialization protocols, and puppy and dog training classes attended. The degree of control over the dog was tested by observation for obedience to three basic commands (sit, come, down) in response to the owners. When dogs suffer persistent serious general anxiety or have one or more stimulus-specific anxieties from an early age on and (1) the dog was as a pup obtained from a remotely located farm and/or derived from a commercial dog breeder and/or trader, or a totally inexperienced

breeder (first nest), (2) no socialization program or social exposure to humans, dogs, and/or other environmental stimuli orchestrated by the breeder (e.g., pups were kept inside, only saw the breeder/caretaker and its own littermates), and (3) if the anxiety shown was not connectable to a previous traumatic moment and/or incidence, we concluded that a lack of early social exposure during sensitive periods (socialization deficiency) was an appropriate component of the diagnosis.

Dogs with dog-killing behavior are mentioned for each of the two data sets: 128 dogs seized dogs are noted in Table 1, and 29 dogs diagnosed with dog-killing behavior were seen at the clinic (Table 3). None of our cases involved dogs in the same household. The results of the two data sets are presented in descriptive statistics. If appropriate and meaningful, test statistics were performed (χ^2 tests were used for comparison and any $P < 0.05$ was considered evidence of association).

Results

Data on seized dogs that attacked and killed or severely wounded dogs, and their victims

The population of seized dogs that had bitten other dogs totaled 176 dogs. The average age of these dogs was 3.8 years (range, 9 months to 14 years). Half of these dogs (N = 88) were intact males, 14% (25) were castrated males, and 36% (63) were females (the reproductive state of the females was not reported). Of these 176 dogs, 128 (73.7 %) were involved in killing or severely wounding (according to police reports and/or reports from veterinarians) one or more dogs. The remaining 48 apparently attempted to attack other dogs, but this did not lead to serious wounds. Breed types of these 128 attackers as derived from police reports are listed in Table 1. These 128 dogs killed a total of 72 dogs. Table 1 shows that more than half of the dogs (56% of 128 dogs) were labeled by owners and/or the authorities as American Staffordshire/pit bull terrier type, and killed 28 dogs (54% of 72 killed dogs) and severely wounded 24 dogs (57% of 42 victims).

Individual dogs mentioned in Table 1 killed or wounded 1-3 dogs, 27 of the dogs operated in groups, the two largest groups consisted of 6 dogs described as pit bull types and 7 American bulldogs respectively. There were five groups that comprised 3 dogs and three groups that comprised 2 dogs. Information on the roles these individual dogs played in the attacks was missing, and test

Table 1
Breed types of the population of seized dogs that killed or severely wounded one or more dogs (data set 2010-2015)

Seized breed types	N dogs	N dogs killed	N dogs severely wounded
American Staffordshire/pit bull terrier type	71	38	24
Mixed breed	19	14	6
American bulldog	10	3	3
Belgian shepherd (Malinois)	3	1	2
Rottweiler	4	3	1
Akita Inu	1	1	
Shiba Inu	1	1	
Presa Canaria	1	1	
Cane Corso	2	1	1
German shepherd	4	1	1
Bull terrier	3	1	3
Australian cattle dog	1		1
Bordeaux dog	1	1	
Bullmastiff	3	2	
Gray hound	1	1	
Anatolian dog	3	3	
Total	128	72	42

results did not provide further indications. In two groups, only one dog was diagnosed with dog-killing aggression on the basis of police reports and subsequent testing, and these two dogs are included in Table 1, but their coattackers were not included.

In two cases, the victim was partially eaten, and in another case, the killed dog was taken away by the attacker and was never found. All attacks took place in public areas. Information of the police reports suggested that some dogs tended to only attack a certain type of dog. In four reports, owners stated that their dog attacked and killed (or wounded) a small dog, after it had barked at the offending dog. However, in 3 of these 4 cases, the owners of the attacked dog did not report such a type of behavior of their dogs.

Table 2 shows the size and the breeds of the victim dogs. From a total of 114 victims, 94 (83%) were of small breeds like Chihuahua, Yorkshire terrier, and Jack Russell terrier or other small (un)identified dog breeds. These findings show that small dogs are the predominant type of victims in our study population. Unfortunately, the breed type of many victims was not specified in the police reports, and overall population prevalence by breed size in the Dutch dog population is unknown. In one case of a severely wounded dog, the police report did not detail whether it survived. Dogs were either killed on the spot or died as a consequence of severe wounds later on.

In a limited number (n = 14; 11%) of police reports, owners of dogs reported additional remarks on the history of the dog that (in their view) was relevant to the development of the behavior of their dog. These owner comments are cited in the following:

> "He started attacking sometime after he was attacked himself" (mentioned 4×). No indication of time line.

> "My dog was bitten at 7 months of age and started to be aggressive towards other dogs after that."

> "He (German shepherd) hated the Jack Russell of my neighbor because that dog always barked at him, when I walked my dog and passed the garden of my neighbor."

> "The only dog he hates is the dog of my neighbor across the street."

> "He has hated dogs for some time." No indication of time line.

> "He cannot stand small dogs" (3×). No further information as to why.

> "He was attacked by a large dog when he was a puppy."

Although limited in number, these remarks suggest that a negative experience with certain dogs may have led to the development of attacking behavior toward dogs in general or toward specific types of dogs. This phenomenon was further investigated by using data from dogs referred to the behavior clinic.

Data on dogs referred to the Veterinary behavior clinic for intraspecific aggression

A data set of 151 dogs referred to the veterinary behavior clinic at Utrecht University for intraspecific aggression was analyzed to explore factors possibly connected to "dog-killing aggression." Of 151 dogs, 75 (66%) were intact males, 22 (20%) were castrated males, and 54 (36%) were females of which 8 (5%) were spayed and 46 (30%) were intact.

Of the 151 dogs, the behavior of 29 (19%) dogs diagnosed conforms with the criteria of "dog-killing aggression" based on the owner's description of behaviors and provided video material. In total, these 29 dogs killed 3 dogs. Six other cases were omitted from further analyses because of uncertain diagnosis. The remaining dogs in this data set (n = 116) were diagnosed with intraspecific

Table 2
The size and breed of the victims of the seized dogs, the numbers of killed and/or severely wounded, and the percentage of total victims per breed type (data set 2010-2015)

Size of victim	N	%	Breed of victims	N killed	N severely wounded	% Of total
			Chihuahua	11	3	12
			Yorkshire terrier	6	1	6
			Jack Russell terrier	10	8	16
Total small	92	83	Other identified small dogs	14	14	24
			Other nonspecified small dogs	11	7	16
			Puppy of nonspecified breed	3	1	4
			Small poodle		1	1
			Dachshund		1	1
			Not identified		3	3
			Spitz		1	1
			Dutch Shepherd dog	1		1
			Border collie		1	1
			Nonspecified breeds	7	2	8
Total medium/large	19	17	German shepherd dog	4		4
			Bouvier des Flandres	1		1
			Labrador retriever	4		4
Total	111	100		72	42	100

The breed/size type of three victims was not identified.

aggression, including preceding threatening acts before their attacks.

Of the 29 dog-killing dogs diagnosed with "dog-killing aggression," 18 were males (8 castrated and 10 intact) versus 11 females (3 spayed; 3 intact and 5 with unknown reproductive status). Table 3 shows the breeds of dogs diagnosed with "dog-killing aggression." A large variety of breeds was involved, with no single breed highly represented.

Analyzing the victims that these dogs attacked according to the criteria mentioned in the introduction, the following picture emerged: 14/29 (48%) dogs attacked only one special type of dog according to their owners (referred to as "specialists" later in the text). Of these 14 specialists, 8 (57%) dogs attacked only small terrier type of dogs, 3 (21%) attacked only large-sized dogs, 1 dog attacked only black/white dogs, 1 attacked only one specific breed, and 1 attacked only large black dogs from different breeds. From 7 of 14 "specialists," dogs being attacked were of the same breed this "specialist" was attacked earlier in life (50%).

Twelve (41%) of the dog-killing dogs attacked (or tried to attack) many different breeds (or even "all breeds") according to the owners (referred as "generalists" later in the text). Two dogs had attacked viciously only one dog (1 killed) so that no trend regarding choice of victims could be established.

When Tables 1 and 3 are compared, differences between the population of dogs seized by the police and the population of dogs visiting the veterinary behavior clinic are obvious: the proportion of dogs identified as American Staffordshire/Pit Bull Terrier type differs significantly ($\chi^2 = 18.8$, $P < 0.0000$). The proportion of high-risk dogs ["high risk" according to a proposal by the Dutch Counsel of Animal Affairs (Raad voor Dierenaangelegenheden, 2017), that advised the Minister on regulations regarding dog bite prevention] differs significantly between the two populations (seized dogs, Table 1 [75/128 dogs] vs. referred dogs, Table 3 [7/29 dogs]: $\chi^2 = 20.0$, $P < 0.0000$).

To investigate possible risk factors associated with the development of normal intraspecific aggression and "dog-killing aggression," data obtained from owners visiting the veterinary behavior clinic regarding potentially relevant life history facts were compared between dogs diagnosed with "dog-killing aggression" (N = 29) and dogs diagnosed with normal intraspecific aggression (N = 86 of the 116) for which we had sufficient information, see Table 4. Table 4 suggests that the main factor associated with the development of "dog-killing aggression" is having been attacked themselves by another dog and that insufficient socialization to other types of dogs is a second factor. A general tendency to hunt on

animals was found to be a rare third cause. The distribution of prospective causal factors for the development of dog-killing aggression and normal intraspecific aggression does not differ ($\chi^2 = 1.22$, $P = 0.874$).

Discussion

Type of dog-killing dogs

A previously compiled set of criteria was used to diagnose a type of aggression for dogs killing or severely wounding other dogs in two populations of dogs, seized dogs, and referred dogs. This set of criteria, applied to the outcomes of behavior tests and data from police reports, was used to label the type of aggression the dogs that killed or severely wounded another dog as "dog-killing aggression" in the seized population. Applying this method, we found that in the population of seized dogs, 56% of 128 cases was of the American Staffordshire or pit bull terrier type. Originally, the American Staffordshire type was associated with blood sports and dog fighting (Clifford, 1983; https://www.akc.org/dog-breeds/american-staffordshire-terrier/). The representation of this breed type in the data

Table 3
Breeds of dogs referred to the veterinary behavior clinic at Utrecht University that were diagnosed with "dog-killing aggression" (data set 2010 and 2015)

Breed type of dog-killing dogs	N dogs
Mixed breed	7
American Staffordshire/pit bull terrier type	2
American bulldog	1
Bullmastiff	1
Bordeaux dog	1
Dobermann	1
Beauceron	1
Briard	1
Labrador retriever	2
Stabyhound	1
Boxer	1
Belgian shepherd (Malinois)	1
Cairn terrier	1
Nova Scotia duck tolling retriever (Toller)	1
Cocker spaniel	1
French bulldog	1
Welsh terrier	1
German pointer	1
Drenth partridge dog	1
Australian shepherd	1
Jack Russell terrier	1
Total	29

Table 4
Prospective factors associated with "dog-killing aggression" or "normal" intraspecific aggression

Factor	29 dogs diagnosed with "dog-killing aggression"	86 dogs with "normal" intraspecific aggression
Started after being attacked by a dog	7 = 24%	24 = 28%
Insufficiently socialized to other dogs	4 = 14%	8 = 10%
Hunts also other animal species	2 = 7%	5 = 6%
Fear of dogs	1 = 3%	4 = 5%
Copies behavior of other dog in household		1 = 1%
Trained as a fighting dog		1 = 1%
Reacted after being barked at by victim	1 = 3%	
Dementia		1 = 1%
No specific factors mentioned	14 = 45%	42 = 51%

Data provided by owners from dogs referred to the veterinary behavior clinic at Utrecht University, the Netherlands.

set of the dogs seized by the police (56%, Table 1) is striking and is not found in the data set of dogs referred to the veterinary behavior clinic (7%, Table 3). This might be caused by a bias among law enforcing officers as they might perceive these dogs as higher risk types compared with other breed types.

However, a second explanation for this bias may be that owners of high-risk dogs tend to have more criminal convictions than other owners as reported by Barnes et al. (2006), and therefore are already known to police officers. Indeed, owners of seized dogs are far more often (16% in 2015) known to the police than the average adult Dutch population (1%-2% of population > 20 years of age according to data from the Central Bureau of Statistics).

A third explanation relates to the owner's behavior: research has shown that owners of high-risk dogs show behavioral tendencies that may differ from those of owners of low-risk dogs (Podberscek and Serpell, 1997; Overall and Love, 2001; Ragatz et al., 2009; Schenk et al., 2012; Wells and Hepper, 2012). This finding suggests that they may behave differently from other, more responsible dog owners. Owners who visited our behavior clinic were actively seeking help for minimizing the danger their dogs (might) pose to other dogs and therefore may be characterized as a more responsible type of owner.

A fourth explanation is that owners of seized dogs (because of their characteristics) more often than owners that contacted the behavior clinic, did choose dogs from breeding lines that were originally bred for dog fighting and/or that their dogs function as status dogs. These dogs might be genetically or epigenetically more inclined to attack other dogs because of the purpose they or their parents were bred for, although scientific evidence is largely missing. Some indications are that male pit bull types that were involved in dog fighting are more aggressive and less social compared with a control group (Capra et al., 2009). Shelter staff and breeders of dogs characterized as American Staffordshire/pit bull terrier types anecdotally report that sometimes puppies in litters have to be separated because of severe biting from a very early age. If true, this may suggest a genetic component in this biting behavior.

Finally, in dogs characterized as pit bulls, comparatively high levels of aggression during the first 9 weeks of life have been documented by Feddersen-Petersen (1994). It is unknown to what degree the population of seized dogs in the Netherlands is representative of those in other countries.

Type of victims

Most victims of seized dogs were small dogs (Table 2), strikingly often of breeds that are anecdotally reported by the owners of the attacking dogs, to behave quite provocative (to their perception, showing tail-up approach, and/or barking) toward dogs, including larger dogs.

Another explanation for the frequent attacks on small dogs may be that certain small breeds are not always recognized as dogs and may be seen as prey. Because dog-killing behavior strongly resembles predatory behavior, it may not well be possible to distinguish motivational factors especially in cases where aggressors also hunt animals of other species. Obviously, small dogs are more likely to end up as fatalities or be severely wounded, leading to a greater probability of police seizing the aggressor than when a larger dog was attacked. This data set does not allow for the conclusion that generally smaller dogs are more likely to be attacked than larger dogs, and conclusions about motivations are speculative.

Factors possibly connected to "dog-killing aggression"

The data set on referred dogs, which included life histories, suggests that there appears to be three main causes for "dog-killing" type of aggression. The first main cause seems to be a prior unpleasant (traumatic) experience with a dog (i.e., the aggressor having been attacked by one or more dogs in the past). Owners regularly reported a relatively fast emergence of serious dog-directed aggressive behavior in the weeks after the incident. This associated factor also emerged from some police reports. The fact that this single potential precipitating factor was mentioned by owners of dogs in both populations in spite of the differences between the two populations is meaningful, especially when one realizes that police officers did not ask owners to describe the development of the dog's aggressive behavior. Therefore, having been attacked by another dog is suggested one of the possible causes of serious dog-directed aggressive behavior.

During consultations in the clinic, owners of victims of intraspecific aggression reported three behavior patterns after an attack. The victimized dog (1) became fearful of (certain types of) dogs while being walked without developing aggressive tendencies, (2) developed rapidly serious offensive aggressive behavior toward dogs, or (3) did not change its response toward other dogs. Possibly these responses are connected to specific coping styles: the dogs that adopt a "dog-killing aggression" style to cope with (some types of) dogs could be designated proactive dogs, whereas dogs that become fearful as more reactive type of dogs. These two distinct coping styles, fearfulness and aggression, were also found by Horvath et al, when they exposed 60 adult German shepherd police dogs to a short-lasting threatening human (Horvath et al., 2007). Although the reactive dogs also showed aggression, the authors attributed this to the type of training these police dogs had received.

An insufficient socialization toward dogs of other breeds is the second factor suggested to lead to the development of "dog-killing" type of aggression but is far less frequently reported as a potential cause. An insightful example was provided by a case seen in the behavior clinic: an owner presented a female American Bull Terrier that was diagnosed with dog-killing aggression. Another dog bred by the same person was seized at an earlier stage because of killing a dog. Both dogs were black and white and so where all the dogs of this breeder. He stated that he did not want his puppies to get on the streets before 12 weeks of age because of the insufficient immunization status. As a result, dogs he bred only had contact with other black and white dogs during their phase of primary socialization (between 3-12 weeks: see Scott and Fuller, 1965). In later life, their dogs showed no aggressive behavior to black and white dogs of other breeds but reacted aggressively toward dogs with other coat colors.

The third main factor is predatory behavior toward all types of animal species. A small percentage (6%-7%, Table 4) of the "dog-killing dogs" from patients seen at the behavior clinic also hunted

other animal species. Hunting other species was also rarely reported in police reports on seized dogs.

Motivations for "dog-killing aggression"

Dogs engaging "dog-killing aggression" might be displaying either uninhibited intraspecific/interdog aggression or predatory behavior. As suggested in Table 4 and by the behavior of the "specialist" dogs diagnosed with "dog-killing aggression," the killing of other dogs was—in most cases where there was sufficient information—likely not predation but uninhibited intraspecific aggression. This conclusion was supported by the fact that a number of dogs limited their attacks to the type of dog that had previously attacked them and not to other dogs. This limitation of types of victims linked to previous negative experiences strongly suggests an intraspecific aggression, and not predatory behavior because the latter would not explain selectivity. However, this explanation is supported by a limited number of cases, which stem predominantly from referred dogs. For the majority of seized dogs, where data on the life history are lacking, we cannot know what factors may be contributory.

The intensity and perseverance of attacking behavior as reported by owners in police reports, and by owners of dog-killing dogs and victims during consultations, and observed during behavioral testing suggest that this behavior must be self-rewarding. The repeated attempts to attack other dogs, regardless of being leashed or punished by their owners, may reinforce the idea of the incentive value of attacking other dogs. The anticipatory scanning behavior that some of these dog-killing dogs displayed illustrates that the sequence is of value to them. Such rewards are likely to play a role in aggressive behavior (Buades-Rotger et al., 2016; Gan et al., 2016). We should remember that getting the opportunity to be aggressive can even be used as an incentive to train animals of many species (references in Fish, 2005), another argument suggesting that attacking may be rewarding.

Fear does not seem to be involved in attacking: "dog-killing aggression" observed during testing was not shown in any of the cases performed in a low posture, and when there was a postural change on seeing an victim, this was upward.

In just a few cases we saw at the clinic, predatory behavior seems a more likely explanation. Owners reported that their dogs were "eager" to find a victim and ran at it and grabbed it without any hesitation or waiting or without prior threatening signals of aggressive intentions. These dogs also were reported to display hunting behavior toward other species. During behavioral testing of the seized dogs, similar behavior was observed. Some referred and seized dogs also hunted other species, so predatory behavior may be involved.

An investigation of 63 fatal intraspecific dingo attacks revealed a preference for a "bite and shake" mode of killing that is typical for medium-sized predators (Behrendorff et al., 2018). This killing behavior corresponds, at least partially, with the behavior of our domestic dog-killing dogs and might suggest more widespread use of predatory behavioral elements.

In most dog-killing dogs, the confrontation with the live stimulus dogs during testing generated a high state of arousal: they showed vigorous movements and fast and/or irregular tail wagging with an upright stiff tail. This behavior is not typical for predatory behavior, as noted, but can be involved in aggression as well.

Remaining questions

The first question that remains to be answered is why some dogs that experienced an attack by another dog develop dog-killing aggression, yet most do not. This might be similar to the question why some people who experience a traumatic event develop post-traumatic stress disorder (PTSD) and most do not. Research has shown that in people who developed PTSD, there were preexisting factors that indicated vulnerability, such as having experienced other traumatic events earlier in life (Nelson et al., 2011; Rincón-Cortés and Sullivan, 2014). In addition, humans at an increased risk for the development of PTSD are shown to have abnormalities in glucocorticoid signaling (Van Zuiden et al., 2012). No equivalent data exist for dogs. Future research should investigate the role of insufficient early social exposure toward other and different dogs as a contributing factor to develop dog-killing behavior. Insufficient socialization may also lead to an increased sensitivity toward potentially harmful events or stimuli, as well as suboptimal mother-child bonding (Rincón-Cortés and Sullivan, 2014; Dietz et al., 2018). A third factor increasing vulnerability may be gene related: offspring of some breeding lines or breeds of dogs may be more at risk.

The second question is why some dogs develop into "specialists," attacking only dogs of the breed or look-alikes by which they, themselves, were attacked. Some generalization may be explained by learning whether "generalists" experienced multiple attacks by several types of dogs. Our data sets do not permit this line of investigation.

Practical implications for testing prospective dog-killing dogs

Behavior testing of dogs to assess the type of dog-killing behavior requires specific use of stimulus dogs because one might easily miss "specialists" that have attacked a certain breed or type of dog. In addition, in the case of seized dogs, police reports should be obtained to get information regarding the type(s) of dogs that have been attacked/killed, the way the aggressor attacked, and the resulting wounds inflicted, with photographic data. These data will inform the types of data to be used in testing. Finally, in the case of seized dogs, it is necessary to obtain information from the caretakers of the dogs with regard to their experience with the seized dogs when these interact with other dogs. This additional information is essential to diagnosis.

Conclusions

We found that having been attacked by a dog, having been insufficiently socialized toward dogs early in life, or having predatory interests in general is a risk factor that predisposes for "dog-killing aggression." These factors may be superimposed on a genetic vulnerability.

In most of our referred cases, "dog-killing aggression" is likely not of a predatory nature but is associated with uninhibited interspecific aggression, specifically fast and silent attacks. The observed perseverance and high arousal suggests that these attacks may be highly rewarding. Dogs with "dog-killing aggression" may limit themselves to attacking the type of dog they had unpleasant experiences with before (specialists) or they may generalize their aggressive behaviors to several types of prospective victims (generalists).

Finally, because experiencing an attack by a dog is a main risk factor for developing fatal intraspecific aggression, this implies that is it important to prevent dogs from attacking other dogs and intervene as fast as possible with therapeutic interventions to counter the impact of being attacked. Failure to do so may turn an attacked dog into a dog-killing dog itself.

Acknowledgments

thanked for their assistance in sampling the data. Inez Schoenmakers is thanked for improving the English language in the article. The authors also thank two anonymous reviewers for their useful comments.

Authors' contributions

Matthijs B.H. Schilder collected the data and wrote the draft manuscript together with Joanne A.M. van der Borg and Claudia M. Vinke. Claudia M. Vinke supervised the submission.

Ethical considerations

The study does not meet the definition of an animal experiment as defined in Dutch Experiments on Animals Act and EU Directive 2010/63/EU. A conclusive assessment is done by the Central Authority for Scientific Procedures on Animals (CCD), the competent authority granting a project license in the Netherlands.

Conflict of interest

The authors declare that no conflict of interest exists in which any author or authors' institution has a financial or other relationship with other people or organizations that may inappropriately influence the authors' work.

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