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Research Paper

Prevalence, comorbidity, and behavioral variation in canine anxiety

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ABSTRACT

Fear is an emotion needed to survive, but when prolonged and frequent, causes suffering in both humans and animals. The most common forms of canine anxiety are as follows: general fearfulness, noise sensitivity, and separation anxiety are responsible for a large proportion of behavioral problems. Information on the prevalence and comorbidity of different anxieties is necessary for breeding, veterinary behavior, and also for behavioral genetic research, where accurate information of the phenotype is essential. We used a validated owner-completed questionnaire to collect information on dogs' fearfulness (toward unfamiliar people, dogs, in new situations), noise sensitivity, separation anxiety, as well as aggressive behavior. We received 3284 answers from 192 breeds. The prevalence estimate for noise sensitivity was 39.2 %, 26.2% for general fearfulness, and 17.2% for separation anxiety. The owner reported the median onset age for noise sensitivity to be 2 years and varied between 8 weeks and 10 years ($N = 407$). High comorbidity was observed between different anxieties: fearful dogs had a significantly higher noise sensitivity ($P < 0.001$) and separation anxiety ($P < 0.001$) compared with nonfearful dogs. Fearful dogs were also more aggressive compared with nonfearful dogs ($P < 0.001$). Prevalence estimates of fearfulness, noise sensitivity, and separation anxiety are in agreement with earlier studies. Previous studies have suggested early onset of noise sensitivity during the first year of life; however, we found a later onset with large variation in the onset age. High comorbidity between anxieties suggests a genetic overlap. Fearful personality may predispose to specific anxieties such as noise sensitivity or separation anxiety.

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Introduction

Fear and anxiety are among the most fundamental emotions required to survive or cope in potentially dangerous or harmful situations (Bateson, 2011; Hohoff, 2009). These evolutionary important and highly conserved emotional states are crucial for the fitness and survival in animals in nature. A fundamental emotion, such as fear, may, however, turn into pathological traits when prolonged and generalized. Anxiety disorders are among the most common disorders in humans with a prevalence of 28% (Kessler et al., 2005) and are part of behavioral problems observed in domestic dogs (Blackwell et al., 2013; Overall et al. 2001).

Research on fear and anxiety in animals is active in several research fields such as in evolutionary ecology, personality research, veterinary behavior, and neurobiology. However, although the studied phenomenon is highly overlapping, the used terminology varies between research fields. Fear and anxiety are both emotions with negative valence; however, fear is suggested to be brief in duration, stimulated by specific stimuli, resulting in active defensive (fight or flight) stimuli, whereas anxiety is prolonged, focused on the future, and does not necessarily have a specific object of threat (Dias et al., 2013; Epstein, 1972; Öhman, 2008). Fear is an emotional state, whereas fearfulness may also be defined as a personality trait, and has been characterized in various ways on the shyness-boldness continuum in animal personality research. A review study on canine personality research found trait fearfulness to be the most frequently emerging personality dimension among 50 publications (Jones and Gosling, 2005).

Fear stimulus activates the sympathetic nervous system with increased adrenaline and noradrenaline secretion and a rise in

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blood pressure and heart rate. The hypothalamic-pituitary-adrenal-cortical system is also activated, which may increase blood cortisol levels. The change in the physiological state alters behavior. Fear is expressed in animals in various ways: avoidance, flight, freezing, and aggression, which (in some cases) are all expressions of fear (King et al., 2003; Palestrini, 2009; Scott and Fuller, 1997). In dogs, behaviors such as panting, salivation, trembling, restless pacing, vocalization, and, in extreme cases, urination and defecation may also be signs of fear (Palestrini, 2009).

In dogs, fearfulness can be categorized into social and nonsocial fearfulness, based on the object and situation (Svartberg, 2007). The social category includes the fear of unfamiliar people and dogs, whereas the nonsocial fear category includes the fear of different objects/situations such as the fear of new situations, loud noises, heights, or shiny or slippery floors. All these specific fears are reported in dogs (Levine, 2009; Lindsay, 2001; Palestrini, 2009); however, their occurrence, comorbidity, age of onset, and affecting environmental factors are not thoroughly studied. An individual's fear and anxiety are considered to be affected both by predisposing genetic factors and environmental factors such as early-life experiences. Dogs can be afraid of unfamiliar people as a consequence of poor socialization or due to aversive experiences (Tiira and Lohi, 2015), but also genetics may have a major role (Murphree et al., 1974).

The fear of loud noises is often referred to as noise phobia in the literature because of extreme panic reactions in some cases. However, we prefer to use the proposed term "noise sensitivity" (Sherman and Mills, 2008) because often fearful behavioral reactions toward loud noises, such as thunderstorms, fireworks, or gunshots, do not fulfill the criteria of phobia. Separation anxiety refers to a behavior which includes signs of anxiety, fear, or phobia expressed by a dog when separated from the owner or from an important person(s) (Sherman and Mills, 2008). Separation anxiety is an intimate part of the human-dog relationship and is also likely dependent on the nature of attachment between the human and the dog (Schwartz, 2003).

The aim of this study was to assess the frequency and comorbidity of fearfulness, noise sensitivity, and separation anxiety in the Finnish family dog population. In addition to anxiety, we also collected information on the frequency and type of aggressive behavior in dogs. We did not divide owner-reported behavior in "normal" or "pathological" categories in this article but rather treated behaviors as continuous traits. This was done for 2 main reasons: first, a proper separation between "normal" or "pathological" behavior would require a clinical population-study setup, which we did not have. Second, treating behavior as a continuous/dimensional trait is most likely much closer to a real situation, in both humans and animals (Gratten et al. 2014), compared to "normal" and "pathological" categories. Data were collected using a validated owner-filled questionnaire, which has been shown earlier to correlate with dog behavior in test situations and to have good test-retest reliability (Tiira and Lohi, 2014).

Methods

Data collection

Data on dogs' behavior and environmental factors were collected using a validated owner-completed questionnaire survey. The questionnaire included altogether 35 questions (Supplement 1), and it has earlier been shown to correlate with dog behavior in test situations (external validity) and to have good test-retest reliability (Tiira and Lohi, 2014). The potential fearful reaction and frequency (0-4) toward unfamiliar people, unfamiliar and familiar dogs, loud noises (after Overall et al., 2006), and in new situations was asked about. To reduce the possible subjectivity of the owner's judgment, we added a question for owners to describe "how exactly" the dog behaved in a specific situation. If the owner reported that the dog was fearful when meeting a stranger (or strange dogs and/or novel situations), the owner had to indicate a specific reaction: how the dog behaves (e.g., the dog withdraws when meeting a stranger). Similarly, if the owner reported that the dog did not show fear toward a stranger, a more specific description of reactions was required to enable our own evaluation of the situation (Tiira and Lohi, 2014). During the data collection, the questionnaire was modified 3 times, resulting in 4 slightly different versions of the questionnaire (the first one being a paper version, the 3 others—online questionnaires). However, the main questions regarding our target traits, fearfulness toward unfamiliar people, dogs, and new situations, noise sensitivity and separation anxiety did not change between the versions. The major difference involved additional background questions to versions 3 and 4 (maternal care, place of birth, type of food, extra nutrients, time spent alone/day, daily exercise) to better document the early-life experiences and conditions of the dogs. Instead of trying to capture the entire spectrum of phenotypic variation in fearfulness, we aimed to structure the questionnaire so that it would identify the most fearful individuals as cases, and those with no marked fear reactions as controls. The frequency and type of aggressive behavior (barking, growling, bite/snap) toward unfamiliar and familiar people and dogs and also toward owners/family members was asked about. Separation anxiety was asked about in only 1 question (yes/no). We derived several independent behavioral variables from the questionnaire data that were later used in the analysis (Table 1).

The questionnaire was advertised for all breeds via breed clubs, the research group's Web pages and Facebook with a focus on the owners of target breeds such as Great Danes, German shepherds, Belgium shepherds, Staffordshire bull terriers, Lagotto Romagnolos and Salukis, due to a large number of existing samples in our Dog DNA bank. Both fearful and nonfearful individuals, as well as dogs with fearful reactions to loud noises and also dogs with no marked behavioral reaction to loud noises were encouraged to participate.

Statistical analysis and behavioral variables used

The comorbidity between fearfulness, noise sensitivity, and separation anxiety was analyzed with chi-square test using binary variables. Fearfulness was defined using fear status, noise sensitivity using noise sensitivity status, and separation anxiety using separation anxiety (see definitions in Table 1). The difference in aggressive behavior between dogs with or without fear, noise sensitivity, or separation anxiety was investigated using the Wilcoxon rank-sum test. The Spearman correlation test was used in the analysis to further investigate the association between fearfulness, noise sensitivity, and aggressiveness.

The fearful behavioral reactions expressed during thunderstorms and fireworks, toward unfamiliar people, and in new situations, were analyzed using Principal Component Analysis (PROC FACTOR, rotation varimax, priors = one, correlation matrix was used, SAS version 9.3; SAS Institute, Cary, NC, USA), and principal components with eigenvalue >1 were selected. Among the loud noises, only thunder and fireworks were included, as there were fewer dogs with marked fearful reactions toward gunshots, and unnecessary reduction of the sample size was avoided in the analysis. Variables with loading values >0.35 were considered to load for a particular component. The Wilcoxon rank-sum test was used to analyze the possible differences in behavioral reactions between fearful and nonfearful dogs, sexes, and sterilization status.

Table 1
Behavioral variables derived from the questionnaire data

Variable	Explanation
Fear status	Binomial (case/control) variable, where case dog shows fear either toward strangers or in new situations/places or unfamiliar dogs at minimum 40% of situations and at maximum 100% in both situations. Control dogs are not reported to show fear in any of the aforementioned circumstances or fear toward strange dogs.
Fearfulness	Categorical variable. Describes the frequency showing fear toward unfamiliar people and in new situations and varies between 0 and 8. Calculated as sum of frequencies (toward strangers [0-4] + new situations [0-4]).
Noise sensitivity status	Binomial (case/control) variable, where case dogs have noise reactivity >0 toward loud noises (thunder, fireworks, gunshot). Control dogs are not reported to show fear in any of the aforementioned circumstances.
Noise reactivity score	Categorical variable. Describes the frequency and intensity of fearful reaction toward loud noise. Calculated as follows: (sum of fearful behavioral reactions to fireworks)* frequency of fear reaction to fireworks + (sum of fearful behavioral reactions to thunder)* frequency of fear reaction to thunder + (sum of fearful behavioral reactions to gunshot)* frequency of fear reaction to gunshot.
Separation anxiety	Binomial (case/control) variable, which is based only 1 question "Does your dog show separation anxiety?" Answers stating that the owners are not certain were excluded from the analysis.
Aggressiveness toward strangers	Categorical variable. The sum variable of the frequencies (0-4) of behaviors barking, growling, snapping, and biting of unfamiliar people.
Aggressiveness toward unfamiliar dogs	Categorical variable. The sum variable of the frequencies (0-4) of behaviors barking, growling, snapping, and biting of unfamiliar dogs.
Aggressiveness toward owner	Categorical variable. The sum variable of the frequencies (1-4) of behaviors barking, growling, snapping, and biting of the owner and family members.

In addition, we calculated the sample size/breed needed to estimate reliable prevalence. The sample size was calculated using the EpiTools sample size calculator (http://epitools.ausvet.com.au), which calculates the sample size required to estimate a proportion (prevalence) with a specified level of confidence and precision. The sample size was calculated using the formula: $n = [Z^2 \times P(1-P)]/e^2$ where Z is the value from standard normal distribution corresponding to desired confidence level ($Z = 1.96$ for 95% CI), P is expected true proportion, and e is desired precision (half desired CI width). We used the following input values: 0.5 for the assumed true value for the proportion, 0.99 for the desired level of confidence, 0.05 for the desired precision of the estimate (+/−), and the size of the population was breed-specific based on the amount of registered dogs in Finland within 10 years.

Results

Demographics of the survey data

Altogether, 3,284 answers (1405 for versions 1 and 2 and 1878 for versions 3 and 4) were received from owners of 192 breeds. Four breeds had over 200 (Lagotto Romagnolo, German shepherd, Saluki, and great Dane) and 6 breeds 80-200 answers (Border collie, Belgium shepherd tervueren & groenendahl, bearded collie, Staffordshire bull terrier, and Shetland sheepdog).

The age of the dogs varied from 3 months to 15 years, where with the mean of 5.2 years ± 3.3, (median 5 years). Data consisted of 1,729 females (mean age 5.3 years ± 3.3) and 1,516 males (mean age 5.1 years ± 3.2). The median age of arrival to the new home from the breeder was 8 weeks (N = 3,012) varying from 0 (born at that home) to 523 weeks (11 years).

Prevalence of fearfulness, noise phobia, separation anxiety, and aggressiveness

Altogether, 1,287 (39.2%) survey participants reported that their dog reacted fearfully to loud noises (noise reactivity >0, Table 1, Figure 1), whereas 1,815 (55.3%) survey responders' dogs did not. Altogether 407 of 1,287 participants with a noise-sensitive dog retrospectively reported the age when the owner first noticed the dog's fearful reactions toward loud noises. The median age of onset was at 2 years, varying from 8 weeks to 10 years (Figure 2). The age of onset was not associated with noise reactivity (Spearman correlation coefficient $r_s = -0.06$, $P = 0.22$, N = 392).

Altogether 26.2% of the responders' dogs (862 dogs from a total of 3,284) showed fear either toward unfamiliar people or in novel situations (see the definition of fear status, Table 1) (Figure 1). More specifically, 21.4% (701) dogs in the survey were reported to show fear toward strangers and 17.9% (588) of participants reported their dog to behave fearfully in new situations. Almost half of the dogs (47.7%, 1,567) were reported not to show fear toward unfamiliar people or dogs, or in novel situations. The survey participants reported 564 dogs (17.2%) with separation anxiety.

The frequency and type of aggressive behavior toward unfamiliar people, unfamiliar dogs, or the owner was also asked in the questionnaire. The majority of the dogs (74.8%, 2455) had shown some form of aggressive behavior toward another, familiar or unfamiliar dog (barked, growled, or bitten). More serious aggression toward another dog was expressed by 1,050 dogs (32% of all dogs); these dogs had bitten or snapped at an unfamiliar dog. A total of 531 dogs (16.2%) showed aggressive behavior (barking, growling, snapping, biting) toward the owner or a family member, and 1478 dogs (45%) toward unfamiliar or familiar people (other than the owner or a family member). Altogether, 12.5% (412) had snapped or bitten people other than family members; and 8.2% (270) had bitten the owner or a family member.

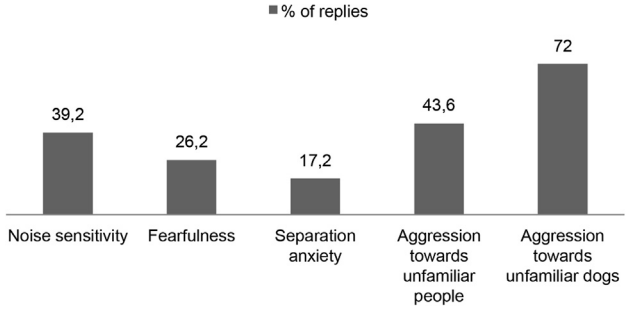


Figure 1. Prevalence of fearfulness and aggressive behavior in dogs. Summary of the prevalence of noise sensitivity, fearfulness, separation anxiety, and aggressive behavior based on the questionnaire survey of 3,284 family dogs. Percentage of dogs that were reported to have noise sensitivity (thunder, fireworks, and gunshot), general fearfulness toward unfamiliar people and new situations (in more than 40% of occasions), separation anxiety, and aggressive behavior expressed as barking or growling or biting or snapping unfamiliar people or dogs.

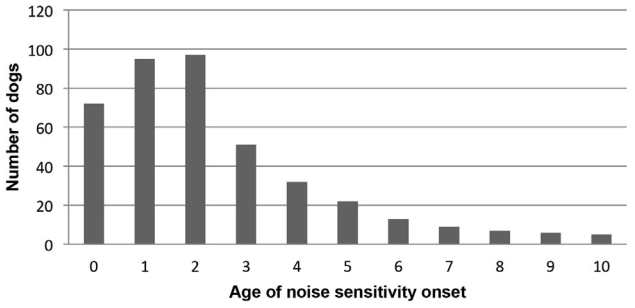


Figure 2. The onset age of noise sensitivity. Distribution of the observed onset age of canine noise sensitivity (N = 407). The median age is 2 years with variation from 0-10 years. 15.1% of the dogs were reported with onset over 5 years.

Anxiety comorbidity—fearfulness, noise sensitivity, and separation anxiety

Fearful dogs had a higher noise sensitivity compared with nonfearful dogs. Among those dogs that had reported their dog to show fear toward strangers and new situations (in 40%-100% of the occasions), 55.9% showed fear toward loud noises, whereas among nonfearful dogs, only 28.8% have reported noise sensitivity (chi-square test $\chi^2_{1,2458} = 173.5$, $P < 0.001$). Among dogs with noise sensitivity, 51.9% were also reacting fearfully toward strangers and new situations at least in 40% of occasions; however, only 25.7% of dogs with no noise sensitivity were fearful ($\chi^2_{1,2458} = 173.5$, $P < 0.001$). Similarly, the frequency of showing fear toward strangers, dogs, and in new situations (fearfulness variable, Table 1) correlated positively with the (sum of) frequencies of reacting fearfully toward loud noises (thunder, fireworks, and gunshots) (Spearman correlation coefficient $r_s = 0.25$, $P < 0.001$, N = 3139).

Separation anxiety also showed comorbidity with fearfulness and noise sensitivity; from those dogs that were reported to have separation anxiety, 58.8% were reported to be generally fearful ($\chi^2_{1,2441} = 125.4$, $P < 0.0001$) and 49.5% afraid of loud noises ($\chi^2_{1,3114} = 26.3$, $P < 0.0001$). However, only 29.8% of fearful dogs ($\chi^2_{1,2441} = 125.4$, $P < 0.001$) and 22.7% of noise-sensitive dogs expressed signs of separation anxiety ($\chi^2_{1,3111} = 27$, $P < 0.001$).

Correlation of fear targets

A more detailed analysis of fear targets revealed that 57.4% of dogs that showed fear toward strangers were also afraid of unfamiliar dogs ($\chi^2_{1,2465} = 553.7$, $P < 0.0001$), and 57.1% were fearful in new situations ($\chi^2_{1,2467} = 606.2$, $P < 0.0001$). Correspondingly, from those dogs that were fearful in new situations, 63.7% also showed fear toward unfamiliar people and 53.5% ($\chi^2_{1,2467} = 606.2$, $P < 0.0001$) toward unfamiliar dogs ($\chi^2_{1,2465} = 553.7$, $P < 0.001$). This comorbidity is also shown in correlation analysis; the more often the dog showed fearful behavior toward strangers, the more often it also showed fear in new situations (Spearman correlation coefficient $r_s = 0.42$, $P < 0.001$, N = 3085), and toward unfamiliar dogs (Spearman correlation coefficient $r_s = 0.42$, $P < 0.001$, N = 3055).

Fear of thunder, fireworks, and gunshot noises had an extremely high correlation; 92.9% of dogs that feared thunder, also feared fireworks ($\chi^2_{1,2910} = 1{,}520$, $P < 0.0001$), and 73.8% of the dogs were also afraid of gunshots ($\chi^2_{1,2346} = 956$, $P < 0.0001$). Similarly, 71.8% and 70.1% of dogs that were afraid of fireworks also reacted fearfully to thunder ($\chi^2_{1,2910} = 1520$, $P < 0.0001$) and gunshots ($\chi^2_{1,2313} = 1237.8$, $P < 0.0001$), respectively. Finally, from those dogs that reacted fearfully to gunshots, 90.3% were afraid of fireworks ($\chi^2_{1,2313} = 1237.8$, $P < 0.0001$) and 74.5% of thunder ($\chi^2_{1,2346} = 956$, $P < 0.0001$). Other loud noises, such as sirens, vacuum cleaners, leaf blowers, and so forth, did not show as high of a correlation as the one observed between thunder, fireworks, and gunshots. From those dogs that feared thunder, fireworks, and gunshots, 53.5% ($\chi^2_{1,2951} = 328.4$, $P < 0.0001$), 50.2% ($\chi^2_{1,2897} = 354.4$, $P < 0.0001$), and 53.3% ($\chi^2_{1,2328} = 304.1$, $P < 0.0001$) feared other noises, respectively.

Fearful dogs are more aggressive

We compared aggressive behavior between fearful and nonfearful dogs, between dogs with and without noise sensitivity, and also between dogs with or without separation anxiety. Fearful dogs were significantly more aggressive toward unfamiliar people, other dogs, and owners, and the same was true for dogs with separation anxiety (Table 2, a and c). Noise-sensitive dogs were more aggressive to unfamiliar people and other dogs, but not toward the owners (Table 2, b).

Behavioral reactions in different situations

In our questionnaire, the owners were able to choose which behavioral reactions they observed in particular fear situations. When the dog was interpreted to behave fearfully toward strangers, the 3 most common behavioral reactions were avoidance/withdrawal, barking (not going toward person), and the low tail position (Table 3). In a new situation, a fearful dog usually pants wants out of that situation or stays close to the owner (Table 3). Fear toward unfamiliar dogs was expressed usually by barking/growling, and either going toward the other dog or withdrawing. Reactions to thunderstorms and fireworks resulted in panting, the low tail position, and trembling, whereas fear reactions to gunshots included pacing, the low tail position, and escape (Table 3).

To explore the behavioral responses in fearful situations further, we performed 3 principal component analyses: (1) behavioral reactions toward fireworks and thunder, (2) toward strangers, and (3) fearful behavior in new situations. The principal component analysis on the reactions toward fireworks and thunder revealed 7 components with eigenvalue >1, explaining altogether 70% of

Table 2
Aggressiveness and anxiety

Trait	df	Z	*P*-value	Sign after Bonferroni[b]
a) Fearfulness (Y/N)[a]				
Aggressiveness toward unfamiliar people	1	16.43	<0.0001	YES
Aggressiveness toward dogs	1	8.86	<0.0001	YES
Aggressiveness toward owner/ family member	1	6.04	<0.0001	YES
Bites/Snaps	1	11.7	<0.0001	YES
b) Noise sensitivity (Y/N)[a]				
Aggressiveness toward unfamiliar people	1	4.05	<0.0001	YES
Aggressiveness toward dogs	1	3.29	0.001	YES
Aggressiveness toward owner/ family member	1	2.51	0.012	NO
Bites/Snaps	1	3.61	0.0003	YES
c) Separation anxiety (Y/N)[a]				
Aggressiveness toward unfamiliar people	1	5.56	<0.0001	YES
Aggressiveness toward dogs	1	4.93	<0.0001	YES
Aggressiveness toward owner/ family member	1	3.45	0.0006	YES
Bites/Snaps	1	3.21	0.0013	YES

Wilcoxon two-sample test comparing the differences in aggressive behavior between a) fearful and nonfearful dogs, b) dogs with or without noise sensitivity, and c) dogs with or without separation anxiety.

[a] Aggressiveness was determined as the frequency of barking, growling, biting, and snapping.

[b] Statistical significance <0.05 after Bonferroni correction is indicated in the last column.

Table 3
The frequency of fearful behavioral reactions reported when meeting an unfamiliar person, or an unfamiliar dog, in new situations, and when hearing loud noises (thunder, fireworks, and gunshot)

Trait	Frequency	%
When the dog meets an unfamiliar strange person, it…		
Avoidance (withdraws)	500	58.55
Barks (is not going toward person)	314	37.34
Tail low/between the legs	245	31.17
Barks/growls AND goes toward a stranger	222	27.78
Not willing to make contact	215	26.84
Stays close to the owner	215	26.84
Growls (is not going toward person)	137	17.27
In a new situation/in a new environment my dog…		
Pants	323	46.14
Wants out of the situation/new space	303	42.2
Stays close the owner (not under any command)	313	41.9
Tail low	296	41.69
Walks low	212	29.82
Tremble	203	29.08
Stays still, does not want to explore the new environment	110	16.15
Barks	70	10.25
When the dog meets an unfamiliar dog, it…		
Barks/growls AND goes toward a stranger	391	51.31
Withdraws	261	36.15
Barks (is not going toward the dog)	280	35.18
Stays close to the owner	184	25.59
Growls (is not going toward the dog)	192	25.33
Not willing to make contact	152	22.19
Tail low/between the legs	152	21.9
My dog reacts to thunder		
Pants	560	64.52
Tail low/between legs	555	63.79
Tremble	481	56.32
Pace	456	54.68
Hide	438	52.39
Escape	285	35.36
Vocalize	159	20.73
Salivate	133	17.43
Freeze	135	17.33
Urinate	19	2.56
Destroy	10	1.35
Defecate	4	0.54
My dog reacts to fireworks		
Pants	707	62.18
Tail low/between legs	689	60.81
Tremble	648	58.01
Hide	580	52.58
Pace	544	50.14
Escape	498	45.48
Vocalize	249	24.46
Freeze	212	20.56
Salivate	174	17.23
Urinate	21	2.14
Destroy	8	0.82
Defecate	6	0.61
My dog reacts to gunshot		
Pace	421	72.96
Tail low/between legs	425	64.59
Escape	315	50.56
Tremble	247	44.7
Pant	245	41.04
Freeze	218	36.27
Hide	153	26.56
Vocalize	83	15.12
Salivate	47	8.53
Urinate	6	1.11
Destroy	3	0.56
Defecate	1	0.19

variation. The loading values (>0.35) of behavioral variables for each component are presented in Table 4. The largest component includes (PCA1) escape and hiding reactions for both thunder and fireworks, as well as trembling and the low tail position. The second largest PCA2 component loads high on pacing and also panting, whereas the PCA3 includes defecation and urination for both thunder and fireworks. PCA4 loads high on salivation as well as panting, PCA5 includes vocalizing, PCA6 destroying, and PCA7 includes freezing for both thunder and fireworks (Table 4).

Table 4
Principal components with eigenvalue >1 grouping different fearful behavioral reactions to fireworks (f) and thunder (t)

Behavioral reaction	PCA1	PCA2	PCA3	PCA4	PCA5	PCA6	PCA7
escape f	0.70						
pant f	0.49	0.61					
hide f	0.80						
tremble f	0.61	0.41					
tail low/between legs f	0.59						
escape t	0.76						
pant t	0.50	0.45		0.42			
hide t	0.83						
tremble t	0.64						
tail low/between legs t	0.65						
pace t	0.37	0.61					
pace f		0.75					
defecate f			0.68				
urinate f			0.82				
defecate t			0.65				
urinate t			0.75				
salivate f				0.81			
salivate t				0.87			
vocalize f					0.83		
vocalize t					0.87		
destroy f						0.88	
destroy t						0.86	
freeze f							0.84
freeze t							0.81

Loading values >0.35 are shown.

The 2 principal component analyses on fear responses toward strangers (Table 5, a) and new situations (Table 5, b) revealed 2 components each. Fearful reactions toward unfamiliar people formed 2 categories: avoidance and being close to the owner (PCA1), and aggression (bark, growl, PCA2) (Table 5, a). Analysis on the fearful behavior in a new situation revealed 2 principal components. The first PCA1 included being close to the owner or wanting out of the situation, and the tail low position, whereas PCA2 included behaviors such as barking, panting, and trembling in a new situation (Table 5, b).

Factors affecting reactions to noise

We investigated whether dogs differ in fear reactions in terms of sex or neutering status. In addition, we further analyzed whether general fearfulness, age, and age of onset is associated with reactions toward loud noises. We found that females, dogs that were sterilized, and more fearful dogs presented more PCA1 behaviors (escape, hide, tremble, tail low) toward thunder and fireworks (Wilcoxon rank-sum test, respectively: $z_{1,\ 2570} = -4.0$, $P < 0.001$; $z_{1,\ 2542} = 5.69$, $P < 0.001$; $z_{1,\ 2024} = 7.62$, $P < 0.001$). Males, unneutered, and nonfearful dogs reacted by urinating/defecating (PCA3) more often ($z_{1,\ 2570} = 2.1$, $P < 0.05$; $z_{1,\ 2542} = -6.21$, $P < 0.001$; $z_{1,\ 2024} = -8.98$, $P < 0.001$), and destroying (PCA6) (respectively, $z_{1,\ 2570} = 2.68$, $P < 0.01$; $z_{1,\ 2542} = -5.76$, $P<0.001$; $z_{1,\ 2024} = -7.89$, $P < 0.001$). Sterilized dogs (of both sexes) showed more panting and pacing toward loud noises (PCA2; $z_{1,\ 2542} = 5.05$, $P < 0.001$) and less vocalization (PCA5; $z_{1,\ 2542} = -4.07$, $P < 0.001$). In addition, fearful dogs expressed more panting and pacing when hearing loud noises (PCA2; $z_{1,\ 2024} = 7.19$, $P < 0.001$) and less salivation compared with nonfearful dogs (PCA4; $z_{1,\ 2024} = -4.88$, $P < 0.001$). Younger dogs had more defecating/urinating (PCA3), freezing behaviors (PCA7), and less salivation (PCA4) compared with older dogs (Table 6). The

Table 5
Principal components with eigenvalue >1 grouping different fearful behavioral reactions to a) unfamiliar people and in b) new situations

Trait	PCA1	PCA2
a) Toward unfamiliar people		
Avoidance (withdraws)	0.75	
Not willing to make contact	0.73	
Stays close to the owner	0.72	
Tail low/between the legs	0.70	
Growls (is not going toward person)		0.70
Barks/growls AND goes toward a stranger		0.64
Barks (is not going toward the dog)		0.63
b) In new situations		
Tail low	0.76	
Stays close the owner (not under any command)	0.66	
Stays still, does not want to explore the environment	0.66	
Walks low	0.65	
Wants out of the situation/new space	0.60	
Barks		0.79
Pants		0.58
Trembles		0.49

Loading values >0.35 are shown.

onset of noise sensitivity was not associated with any of the specific behavioral types.

Avoidance (PCA1) and aggressive (PCA2) types of behavioral reactions toward strangers did not differ between sexes or neutering status; however, females had slightly more avoidance behaviors, a finding that was not significant in a large sample ($z_{1, 2570} = -1.90$, $P = 0.058$). In new situations, males ($z_{1, 2570} = 2.09$, $P = 0.037$) and sterilized individuals showed ($z_{1, 2542} = 2.56$, $P = 0.010$) more panting, barking, and trembling (PCA2) behaviors.

Breed differences in behavior

To have a valid and reliable estimate of prevalence, the sample size has to be sufficient and randomized. We calculated the sample size per breed for a prevalence estimate based on the number of registered dogs in Finland within the last 10 years. However, none of them reached the estimated sample size needed to report a reliable breed-wise prevalence. We received >200 replies from 4 breeds: German shepherd (558 replies received, 641 needed); great Dane (317 replies, 552 needed); Lagotto Romagnolo (208 replies, 544 needed); Saluki (239 replies, 386 needed). In addition, the data collection in this study was not randomized. Therefore, we report the results only on breed averages for noise reactivity (how intensively the dog reacts to loud noises) and owner-directed aggressiveness (behavior not specifically advertised when the questionnaire was distributed). We found that Lagotto Romagnolo had significantly higher noise reactivity and also the highest owner-directed aggression compared to other breeds (Figure 3A and B).

Discussion

A detailed understanding of the prevalence and comorbidity of anxiety traits across breeds is not only important for the welfare (Dreschel, 2010; Sonntag and Overall, 2014) and management of

Table 6
Spearman correlation coefficients on the association between behavioral reactions to thunder and fireworks (PCA1-PCA7, Table 4) and age of the dog and age of the onset of noise reactivity

Trait	PCA1	PCA2	PCA3	PCA4	PCA5	PCA6	PCA7
Age of the dog N = 864	ns	ns	**−0.12**	**0.15**	ns	ns	**−0.16**
Age of onset N = 327	ns	Ns	ns	ns	ns	ns	ns

Bold values are significant after Bonferroni correction for multiple testing ($P < 0.05$).

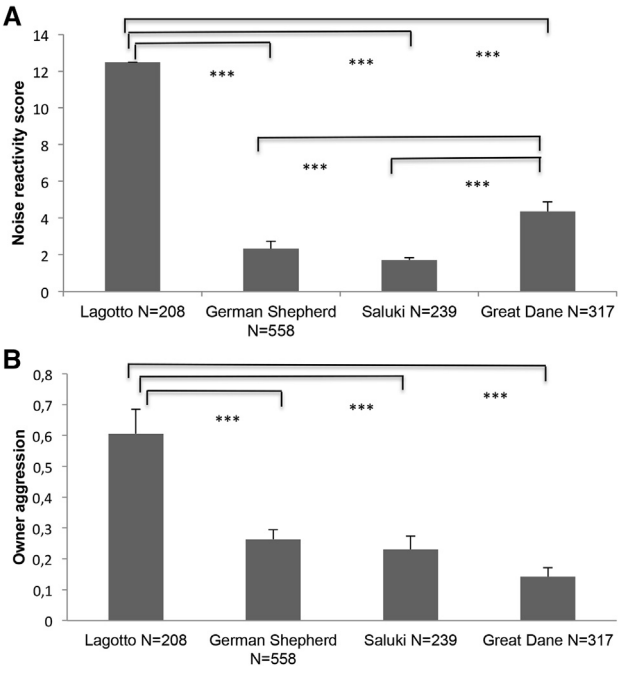


Figure 3. Breeds differ in noise reactivity and owner-directed aggression. Summary of breed-specific differences in (A) noise reactivity and (B) owner-directed aggression. Mean values (±SE) are presented in 4 breeds which all have replies >200. Statistical significance after Bonferroni correction of pairwise comparisons between breeds is marked with *** ($P < 0.001$).

dogs to avoid fear-induced aggressions, but also to develop informed breeding plans, and efficient research strategies for successful genetic studies. This study used our previously validated online questionnaire to capture a large data set from over 3200 dogs from 192 breeds covering the most common canine anxiety traits: fearfulness, noise sensitivity, separation anxiety, and aggressive behavior. It is important to note that this data is based on the owners' assessment of their dogs' behavior, and no clinical examination or behavioral diagnosis for these dogs was done. Therefore, these data may include erroneous interpretations. The owners' subjective assessments of their dogs' personality has often been questioned; however, the owners' behavioral evaluations, and particularly of fearful behavior, have shown strong correlations with expert behavioral assessments (Gosling et al., 2003; Jones and Gosling, 2005; Tami and Gallagher, 2009; Tiira and Lohi, 2014).

Prevalence of anxiety and aggressiveness

Although it has been stated that fear-related problem behaviors in dogs are common, relatively few prevalence estimates on fear toward strangers or new situations has been reported in dogs. In this study, we invited both fearful and noise-sensitive dogs as well as "control" dogs with no marked fear reactions to participate in our research. Although owners of noise-sensitive or fearful dogs may be more prone to participate this study, we also received replies from 1,567 nonfearful dogs and from 1,957 dogs without noise sensitivity. Our study reached prevalence estimates comparable to earlier studies. The prevalence of general fearfulness in our study population was 26.2% (fearfulness being determined as a fearful reaction >40% of times toward unfamiliar people and novel situations), and 21.4% for fear toward strangers. According to an unpublished survey data, 22% of responders reported their dogs showed fear toward unfamiliar adults, and 33% toward unfamiliar children (Voith and Borchelt, 1996). Similarly, our estimate for the

noise sensitivity (39.2%) was comparable with earlier frequency estimates: 38% (Voith and Borchelt, 1996), 25% and 49% (Blackwell et al., 2013), 20% (Mills, 2005), 51.7% (Martínez et al., 2011) for noise phobia. We observed 18% frequency of separation anxiety, which agrees with earlier estimates of 20%-40% (of behavioral clinical patients) (Horwitz, 2012) and 20% (Martínez et al., 2011), although much higher estimates have also been found (34%) (Blackwell et al., 2013). However, more information on the actual behaviors that are interpreted as separation anxiety is needed to get reliable estimates on the frequency of this behavioral problem.

Aggressive behavior is diagnosed in 70% of the clients coming to the veterinary behaviorist clinic (Beaver, 1994; Landsberg, 1991; Patronek and Dodman, 1999), and it is estimated that 15.8 bites per 1000 people occur in the United States every year (Gilchrist et al., 2008). Aggressive behavior (barking, growling, or biting) toward unfamiliar people was reported in 43.6% of replies; however, it is important to remember, that this number also includes occasional and infrequent aggressive behaviors. Bites and snaps, on the other hand, indicate more severe aggressive behavior, and the frequency in our data was 12.5% toward unfamiliar people and 8.2% toward family members. Earlier studies have reached lower prevalence estimates of aggressiveness: stranger-directed aggression 4.7% and 2% for owner-directed aggressive (Duffy et al., 2008). In another more recent study, 7% reported aggression toward strangers entering a house, 5% reported aggression outside the house, and only 3% reported owner/family member–directed aggression (Casey et al., 2014).

Onset of noise sensitivity

The onset of noise sensitivity was investigated in a subsample (N = 407), revealing a median onset at 2 years. Sherman & Mills (2008) have suggested that noise sensitivity usually starts by 1 year of age; however, our results do not agree with their finding. In our study, noise sensitivity was observed in as late as 10-year old-dogs. Late-onset age for storm phobia has been observed in an earlier study, where the median onset age was found to be 6.5 years (Bamberger and Houpt, 2006). Older dogs were found to have more noise sensitivity in other studies (Blackwell et al., 2013; Dale et al., 2010), which may also reflect the later onset age in these studies. Against the general belief, noise sensitivity in dogs is seldom a result of simple traumatic experience (Levine, 2009). Several mechanisms, such as traumatic experience, lack of habituation, stress-induced dishabituation, social transmission, and sensitization, have been suggested (Levine, 2009; Sherman and Mills, 2008). However, high heritability estimates (van der Waaij et al., 2008) also suggest a strong genetic compound. Noise sensitivity, in general, has been poorly studied, and only 1 study has reported the hearing ability of the affected dogs (Scheifele et al., 2016, this issue). It has been suggested that dogs with noise phobia might feel pain as a result of the loud noise, and some physiological studies give some support for this hypothesis (Hydbring-Sandberg et al., 2004).

Comorbidity of fear, noise sensitivity, and separation anxiety

Our results suggest a clear comorbidity between a dog's general fearfulness and noise sensitivity. Fearful dogs seem to have a higher likelihood of developing sensitivity to loud noises compared to nonfearful dogs (51.9% vs. 25.7%). Fearful dogs also express noise sensitivity differently compared to nonfearful dogs. In general, a fearful personality may predispose a fear of loud noises. In a recent study with rough collies, high genetic correlations were found between nonsocial fear, the curiosity/fearfulness–personality dimension, and gun shot-reaction, indicating a large genetic overlap between these traits (Arvelius et al., 2014). A recent study found a positive correlation between hair cortisol and behavioral reactivity to loud noises (Siniscalchi et al., 2013). Interestingly, in that study, the hair samples were collected 2 weeks after exposure to a thunderstorm and, therefore, do not represent an acute hypothalamic-pituitary-adrenal-cortical reaction, but give support to the hypothesis that noise-sensitive dogs are generally emotionally reactive, or have underlying temperament differences.

Separation anxiety was the only trait that was asked about in only 1 question in our questionnaire (yes/no), and therefore, this category has the largest subjective component in our study. Dogs assessed by their owners to have separation anxiety were more likely fearful and had noise sensitivity in our study, but at the same time, only one-fourth of the fearful or noise-sensitive dogs had separation anxiety. This suggests that most dogs that suffer from separation anxiety are generally fearful, and half of them have a fear of loud noises. Separation anxiety and noise sensitivity have been suggested to overlap (Overall et al., 2001; Palestrini et al., 2010; Sherman and Mills, 2008); however, some studies did not find any correlation between separation anxiety and noise sensitivity (Blackwell et al., 2013). Dogs with separation anxiety were found to behave in a more pessimistic way compared with dogs with no separation anxiety in cognitive bias testing (Karagiannis et al., 2015; Mendl et al., 2010), supporting the underlying personality differences.

In humans, comorbidity between different anxiety disorders is often found. Moreover, high scores in neurotism increase the risk of diagnosis of any anxiety disorder (Hettema et al., 2006). In general, the correlations between behavioral traits with a common underlying mechanism are expected to be stronger than between traits with independent mechanisms (Sih et al., 2004). Recent advances in human psychiatry genetics have suggested that many diagnostically different anxiety disorders actually share several risk loci (Zhu et al., 2014). In search of a biological mechanism of canine anxiety, it might be useful to analyze distinct traits separately and in combination.

Fear—a major motivator for aggression

In our study, fearful and noise-sensitive dogs were reported to behave more aggressively toward unfamiliar people and dogs compared with dogs with no anxieties. The owners of 673 dogs reported that their dogs express fear by barking, growling, and approaching a stranger (Table 3). This result suggests that aggressive behavior observed in these dogs is defensive in nature; moreover, owners in this study seem to be able to interpret their dogs aggressive behavior as fearful. Aggressiveness can be categorized into several classes in dogs, where one of the most common facilitators of aggressive behavior is fear (Overall, 2013). Compared to earlier studies, we found a relatively high percentage of bites and snaps toward unfamiliar people and owners/family members. The reason for the high estimates observed may well indicate that owners of very fearful dogs were encouraged to participate in this study. The largest study on canine personality did not find any correlation between the shyness-boldness personality dimension and aggressiveness using DMA test as an assessment of personality (Svartberg and Forkman, 2002); however, the authors later suggested that the DMA test does not assess a dog's aggressiveness accurately (Svartberg, 2005). In wild animals, aggressiveness is generally found to correlate with boldness and risk taking (proactive personality) (Groothuis and Carere, 2005); however, in humans, aggressiveness is a characteristic associated with anxiety and depression (Neurotism) and also with antisocial behavior (Agreeableness) (Caramaschi et al., 2013). To properly compare a domestic dog's aggressive behavior to a wild animal's behavior, the dog's aggressive behavior should optimally be measured in a

situation without an owner, as the owner's behavior may greatly affect the dog's defensive behavior, and owners may unintentionally give enough support for the dog to show aggressive behavior.

Thunder, fireworks, and gunshot fear have a high correlation

Sensitivity to different types of loud noises (thunder, fireworks, and gunshots) had a high correlation; if the dog was afraid of one noise, it was most likely afraid of all others as well (70.1%-92.9%). Dale et al. (2010) found that 68% of dogs that were afraid of fireworks were also afraid of thunder, gunshots, and other loud noises. Several studies also suggest that dogs may associate noises to other associated components as well such as lights in fireworks, and wind, rain, and barometric pressure in thunderstorms (Crowell-Davis et al., 2003; Mills, 2005). Thunder, fireworks, and gunshots all have rather similar dB (110-130 dB) (Levine, 2009), compared to other noises, and it may be that this similarity causes the strongly correlated behavioral response in dogs. In addition, the behavioral reactions toward these 3 noises were very those characterized as similar. Both thunder and fireworks triggered pacing, hiding, trembling, panting and low tail position most frequently (>50% frequency), and in addition to previous behavior, escape was also frequently observed as a consequence of gunshots.

Fearful reactions differ between sexes and neutering status

Loud noise triggers an acute stress reaction in a noise-phobic dog, where it usually tries to avoid the noise by escaping, hiding, or freezing (Ogata and Dodman, 2011). In a fearful situation, dogs may behave either actively or passively, and the major component in our principal component analysis for thunder and fireworks included mostly active behaviors (PCA1: escape, hide, pant, tremble, tail low). This active avoidance behavior was more commonly observed in sterilized, and more fearful individuals. Males, not sterilized, and not generally fearful dogs showed more urinating, defecating, and destroying as a response to loud noises. Females also had a non-significant tendency to show more avoidance-type fear behavior toward unfamiliar people, whereas males and sterilized individuals had a more excited/active type of behavior in new situations. Sterilization in Finland is not routinely done, and especially for males, it is done relatively rarely. One of the major reasons, in males particularly, for castrations are behavioral problems, such as aggression, and/or hyperactivity, which may partly explain the observed difference in excited/active type behaviors between sterilized and nonsterilized dogs.

Breed differences in behavior

Differences in fearfulness and aggressive behavior between breeds may be expected as breeds have originally been intensively selected for different purposes. However, it is important to understand how breeds differ, including breed-specific anxiety profiles, for more efficient research strategies and breeding plans. Breed-specific comparisons in this study must be interpreted with caution due to insufficient samples sizes for reliable estimates on the prevalence of various anxiety traits. The comparison of noise reactivity and owner-directed aggressiveness between 4 breeds revealed that the Lagotto Romagnolo breed had significantly higher noise reactivity compared to other breeds. Similarly, Lagotto Romagnolo owners reported the highest frequencies of owner-directed aggressiveness. Breed comparisons may suggest large breed-wise differences in the magnitude of fear reactions toward loud noises. In earlier studies of breeds, retrievers, spitzes, and poodles have suggested to have a higher prevalence for noise phobia (McCobb et al., 2001; Mills, 2005). Statistics on owner-directed aggression often find breeds such as pitbull terriers or Rottweilers to have high rankings (Sacks et al., 2000). However, many studies have found high owner-directed aggressiveness rates in medium and small-sized breeds (Duffy et al., 2008; Hsu and Sun, 2010), where the Lagotto also belongs (as a medium-sized breed). Behavioral traits, such as fear of loud noises (van der Waaij et al., 2008) and aggression (Liinamo et al., 2007; Trut et al., 2009), have been observed to have relatively high heritability values in dogs, and if no attention is paid to these traits in breeding, rapid changes may occur in small breeding populations. Larger breed-wide comparisons are warranted in the future for a better understanding of the behavioral patterns.

Conclusions

We found relatively high estimates for incidence of general fearfulness across breeds with high comorbidity between noise sensitivity and separation anxiety. From the welfare point of view, it is worrying to observe that one-fourth of dogs are reported to experience fear in almost half of situations when meeting strangers or new places. And especially so because our results support the finding that fear appears to be a significant motivational factor for aggressive behavior toward the owners as well. Canine anxiety traits may share common genetic risk factors, and the underlying fearful personality may predispose individuals to develop specific anxieties such as noise sensitivity and separation anxiety.

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Conflict of interest

The authors declare no conflict of interest.

Supplementary Data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jveb.2016.06.008.

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