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Not a one-way road—Severity, progression and prevention of firework fears in dogs

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Abstract

Noise fears represent a highly prevalent welfare problem in dogs. An online survey was performed to explore severity and progression of firework fears in dogs, and relationships with demographics, health, behaviour problems and owners' training efforts to prevent or alleviate firework fears. Fifty-two percent of dogs in the sample (N = 1225) were at least partially affected by firework fears, and the majority developed a fear of fireworks in the first year of life, with a decreasing frequency of new occurrences up until seven years, and only few newly affected dogs beyond this age. While almost three-quarters of fearful dogs had recovered by the next morning following firework exposure, recovery took up to one day in 10%, up to one week in 12%, and several weeks or even months in >3%. Univariate analyses indicated a significant effect of breed group, age, sex, neuter status, origin and age at acquisition on severity of firework fears in dogs. However, binomial models including multiple predictors of presence/ absence of firework fears identified only age, breed group (mixed breeds being most affected), health problems, and an interaction between health problems and age as significant predictors. This discrepancy might be explained by collinearities of predictors and underlying differences between mixed-breed dogs and purebreds, such as mixed breeds being acquired from shelters more often and being neutered more often. Firework fears are highly correlated with fears of gunshots and thunder, and to a low extent with fears of other noises, but not with any other behavioural problems. Both improvement and deterioration of firework fears were frequently reported. While an early age of onset and breed differences point to a strong genetic contribution to firework fears, the data indicate that training puppies or non-fearful adults to associate the noise with positive stimuli is highly effective in preventing later development of firework fears.

Introduction

Fear of noises is highly prevalent in dogs and represents a significant welfare concern, with up to half of the pet dog population affected [1–3]. Yet, only a minority of pet owners seem to seek professional advice regarding this issue [2,4], and while some studies investigated treatment options (e.g. [5–10], there is a lack of research on preventive measures.

At present, no unified terminology exists in the field, and different authors refer to fear of noises as "noise sensitivity" e.g. [11], "noise reactivity" e.g. [12], "noise aversion" [13] or "noise stress" (reviewed by [12]). Further distinctions are often made between "fear" (an adaptive response to a stimulus considered to be potentially dangerous), "anxiety" (anticipation of a negative outcome, lacking a specific eliciting stimulus)[1,14], and "phobia" (an extreme, long-lasting reaction which can be elicited by a low stimulus intensity and in human psychiatry is considered irrational; reviewed by [2]). However, as Overall et al. [12] point out, studies are typically lacking sufficient criteria to differentiate between terms such as "reactivity" or "phobia" in dogs, and moreover even in the most commonly used rodent model species to study fear and anxiety, the states of fear and anxiety can often not be differentiated behaviourally (reviewed by [14]). Therefore, in the remainder of the paper I will use the term "noise fears" or "firework fears" to denote any fearful, anxious, stressed or phobic reactions of dogs when exposed to noises or fireworks, respectively.

Fireworks appear to be the most common trigger of noise fears in dogs, although the great majority of affected dogs concomitantly show fear of gunshots and thunderstorms [1,2,12]. Breed or breed group has consistently been identified as being associated with different susceptibility to firework fears [1–3,12], pointing to contributing genetic factors. While the observed breed differences in noise fears are likely polygenic [12], a few genes contributing to noise fears in some breeds have recently been identified [15,16]. Meanwhile, the fact that crossbreeds were the group with the highest incidence of firework fears in [2] points to possible environmental influences (i.e. socialisation experiences) associated with the dogs' origin.

Besides breed, age is a common risk factor, with the prevalence of firework fears increasing with age [1–3]. While fear of noises is usually observable at an early age (median onset: 2 years in [3]), one possible factor contributing to the development of noise fears may be pain, and this may explain why in some dogs an onset of noise fears occurs at a later age: In a recent study comparing ten noise-sensitive dogs with an underlying muscoskeletal pain problem and ten noise-sensitive dogs with no detectable pain, the age of onset was almost four years later in the dogs affected by pain (mean 6.5 years), compared to the others (mean 2.67 years)[17].

Regarding the effects of sex and neuter status on noise fears in dogs, studies have yielded inconsistent results. Both intact females and neutered dogs of both sexes had a higher incidence of noise fears in [1]; in contrast, no effect of sex or neutering was found in other studies [2,4]. Origin of the dog (e.g. rescue, pet shop, breeder, etc.) could be expected to affect fearfulness in dogs due to likely being associated with differential socialisation experiences; nonetheless, this variable did not influence degree of firework fears in [4]. In [2], the only significant effect of origin was for dogs bred by their current owner, which had a lower incidence of noise fears compared to dogs from other sources (breeder, rescue centre, or other including pet shop).

Although a number of publications describe behavioural reactions of dogs when exposed to loud noises (e.g. trembling, freezing, panting, salivation, lowered body posture, tucked tail, hiding, escape attempts, social withdrawal, pacing, involuntary elimination, and destructive behaviour with or without self-injury [3,12,13,18–21]), there is a lack of knowledge on how long such behavioural changes as a result of firework exposure typically persist. One study reports that the median duration of behavioural changes in the aftermath of a firework was two hours (with a mean of 1.83, SD 0.044 [4]), but little is known about the distribution of responses, and how many dogs may be affected beyond the timeframe of a few hours. This detail is, however, of great importance in relation to dog welfare. When behavioural effects persist beyond the time of direct exposure, especially if they last several days or even weeks to months, this would indicate a significant welfare impairment.

Another question of interest relates to the progression of firework fears in dogs, i.e. are they typically stable once developed or is a deterioration inevitable? It has been shown that behaviour problems other than noise fears, including fearfulness (encompassing fear towards people, dogs, handling and non-social fear) and aggression, typically increase over time [22]. Regarding noise fears, some small-scale studies investigated the effects of therapeutic interventions (e.g. [6,10,21,23,24]), but only one larger scale questionnaire study asked owners to describe dogs' changes in firework fears over time, and this study used change in fear as dependent variable in further analyses without providing descriptive statistics [4]. The survey by Blackwell et al. [2] indicated that spontaneous recovery from noise fears may be possible in a small number of individuals, although for half of these animals, loss of hearing appeared to be the responsible factor. Thus, although it is generally assumed that noise fears usually get worse over time (e.g. [12], in line with the finding that noise fears increase with age [1–3]), very little is known about patterns of progression at a population level.

Finally, despite a number of publications on intervention to treat firework fears in dogs [5–10], an important issue that seems to be comparatively neglected is how to prevent fears of fireworks in dogs from developing in the first place. One study indicated that playing the radio during feeding time in German shepherd puppies between the ages of 16 and 32 days led to more favourable responses to sudden loud noises when tested in a puppy test at the age of seven weeks [25]. On the other hand, no beneficial effects of gradually increased auditory stimulation from the age of three weeks was found when 7-week old puppies (German shepherds, Belgian Malinois, Dutch shepherd, and crosses between these breeds) were exposed to sudden noises in a behaviour test [26].

For working dogs, it has been recommended to gradually introduce potentially fear-provoking stimuli to achieve habituation, while pointing out that "the relative risk of habituation or sensitization will vary with characteristics of the stimulus, the personality of the dog, and the state of the individual animal at the time of stimulus presentation" [27]. Initially, the stimulus intensity should be chosen as low as possible to ensure that it is below all animals' startle threshold. Animals with already established fears should be identified through preliminary tests and undergo tailored training "including desensitization, counterconditioning, prior to controlled exposure, and habituation" [27]. However, more research is needed on how to create the most resilient dogs, both when puppies are still at the breeders, as well as when they are with their new owners or handlers.

Thus, the current study aimed to investigate:

1. prevalence and severity of firework fears in pet dogs, age of onset and demographic influencing factors, as well as time until recovery after firework events,
2. co-occurrence of firework fears with other behavioural problems, and
3. progression and prevention of firework fears in pet dogs, and whether this could be influenced by owners' training efforts.

Methods

Ethics statement

Participation in the questionnaire study was voluntary and participants were informed that they could quit the survey any time, and that no data would be saved until they hit the "Submit" button at the end. Respondents were not required to disclose any personal information other than the country of origin and their level of experience with dogs. All respondents whose answers were included in the analyses gave their consent for the information provided

to be used for scientific analysis. For these reasons, no ethical approval was required for the study.

Questionnaire survey

An online questionnaire survey (in an English and a German version) was distributed to a sample of dog owners via our research group's website and social media. The advertisement stressed that dogs both with and without fear of fireworks were of interest, aiming to avoid a response bias towards owners of dogs that were affected by firework fears.

The questions covered the owners' consent for the use of their data, demographic data about the dogs (breed, date of birth, sex, neuter status, country, source of dog, age at acquisition) and dogs' health problems. The breeds were classified post-hoc into groups according to the FCI classification. If at least ten individuals belonged to a FCI group, they were subsumed as that group; otherwise they were categorised as "Other". In mixed breeds, dogs with parents from the same FCI group were categorised as belonging to that FCI group, while crosses of parents from different FCI groups or of unknown breed origin were grouped as "mixed breeds". For the FCI Group 2 (Schnauzer and Pinscher), there were enough individuals from the sections "Pinscher" (N = 15) and "Molossians" (N = 52), respectively, to warrant including these sections as separate breed groups, and likewise I differentiated between "Retrievers" (N = 103) and "Flushing dogs" (N = 20) of the FCI Group 8 "Retrievers—Flushing Dogs—Water Dogs".

To gather information on potential behavioural problems, owners were asked to rate their level of agreement with a number of statements (for example "My dog is afraid of other dogs" or "My dog defends resources against humans") on a 5-point Likert scale ranging from "disagree strongly", "tend to disagree", "partly/partly", "tend to agree" to "agree strongly".

Firework fears: Welfare Impaired score. One main dependent variable for the analyses is the "Welfare impaired score", which is based on the question "Please rate your level of agreement with the following statement: The overall welfare of my dog is strongly compromised by fireworks". As the abovementioned scores, it was answered on a five-point Likert scale from "disagree strongly" to "agree strongly".

Firework fears: Fear progression score. The other main dependent variable for analysis is the "Fear progression" score, which was based on the question "How has your dog's fear of fireworks progressed in the last years?", with the following response options "My dog was never afraid of fireworks", "The fear has improved greatly", "The fear tends to have improved", "The fear has remained the same", "The fear tends to have become worse", "The fear has become much worse" or "I don't know". In the subsequent analysis, this question was only analysed for dogs that were affected by firework fears (Welfare Impaired score ≥ 3), so the answers "My dog was never afraid of fireworks", and "I don't know" were removed from the sample.

Further questions relating to firework fears included "How long does it take until your dog's behaviour is completely back to normal following a firework?" and "At what age did fear of fireworks first become apparent in your dog?" Owners were also asked whether they had attempted any training to prevent or treat firework fears in their dogs, and if so whether training was commenced when the dog was still a puppy, an adult (before the onset of any firework fears), or after the dog had already shown a fear of fireworks. All relevant questions are available in Table A in S1 File.

Analysis

Statistica 6.1 (Statsoft Inc. 1984–2004) was used to calculate non-parametric statistical tests, IBM SPSS Statistics Version 23 (IBM Corporation and its licensors 1989, 2015) was used to

calculate a Principal Components Analysis (PCA), and R version 3.3.3 (2017 The R Foundation for Statistical Computing) was used to compute binomial models.

For the purpose of analysis, the Likert responses were converted to numbers of 1 ("disagree strongly"/ "The fear has become much worse") to 5 ("agree strongly"/ "The fear has improved greatly"). Health problems received a binary score (0 –no health problems; 1 –one or several health problems).

Age of onset of firework fears. To calculate the relative frequency of age of onset of firework fears in dogs, for each age group I calculated the proportion of dogs for whom the onset of firework fears was reported at that age, divided by the total number of dogs having reached this age in the sample.

Demographic influencing factors. In order to assess associations between demographic and training factors with severity or progression of firework fears in dogs, non-parametric statistics [28] were performed as the dependent variables were ordinal scores, but not all model assumptions for ordinal models [29] were met. Kruskal Wallis tests were used to test for differences between dogs of different sexes/ neuter status (four groups: male intact, male neutered, female intact and female neutered dogs), differences between breed groups, and between dogs of different origins (e.g. homebred, large-scale breeders, rescue abroad etc.; see details in Table A in S1 File).

However, the non-parametric approach allowed to test the effects of only one factor at a time. Yet it cannot be ruled out that some of the predictor variables, such as source of dog, breed and neuter status, might be confounded, with dogs obtained from rescue shelters being more likely to be neutered and of mixed breeds. Furthermore, an interaction between age and health problems might be expected in view of a recent study suggesting that onset of noise fears occurred at higher ages in dogs with muscoskeletal pain compared to those not affected by muscoskeletal pain [17].

Therefore, to address the possibility of interactions between some predictors, selected binomial logistic regressions ([30]; function glm in R, Type 3 Sum of Squares) were calculated with the predictors Sex*Neuter status, Age*Health problems, breed group, source of dog, and age at acquisition as independent variables and a binary "Welfare Impaired" score (re-classified from the 5-point scale) as dependent variable. For this binary score, dogs with a Welfare Impaired score of 1–2 were considered as "not fearful" (0), while dogs with a Welfare Impaired score of 3–5 were considered as "fearful" (1). A step-wise model selection approach based on Akaike's information criterion (AIC) was used to select the best model.

Relationship of firework fears with other behavioural problems. A principal components analysis (PCA, [31]) was performed over all questions relating to behavioural problems other than fireworks. As the main aim here was not data reduction, but to detect structure in the data, the number of components retained was not based on a Scree plot or Eigenvalues, but a higher number of components that were biologically meaningful were retained. These seven components covered 83.5% of the variance in the data. Spearman rank correlation tests were performed to assess correlations of the components with the Welfare Impaired score.

Effect of training on prevention and treatment of firework fears. The effect of training was firstly assessed for the full sample (Welfare Impaired scores ranging from 1–5). The Welfare Impaired score was compared for dogs having received targeted training to prevent noise fears as puppies, those having received such training as adults before developing any noise fears and dogs that did not receive preventative training, using a Kruskal Wallis test. Secondly, in dogs already affected by firework fears (Welfare Impaired scores of 3 and above), a Mann Whitney U test was conducted to compare Fear Progression scores in dogs that had received behavioural training compared to those that had not. To take into account the possibility that dogs that received training concurrently received anxiolytic medication, which might have

contributed to the observed improvement, a Chi^2 test was calculated to compare the frequency of use of medication in fearful dogs with and without behavioural training.

Correction for multiple testing. Even when applying the conservative Bonferroni correction for multiple testing, all significant results remained significant, and the original p-values are reported in the Results. For Kruskal Wallis tests, post-hoc testing for between-group differences was performed using Statistica's inbuilt algorithm after [28], and adjusted p-values are reported.

Results

Descriptive statistics

After removing dogs younger than one year at the time of the questionnaire response, 1225 valid responses were obtained, including 527 English and 699 German responses. Respondents were from all over the world including Australia, Austria, Canada, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Israel, Italy, Lebanon, Luxembourg, Malaysia, Mexico, the Netherlands, New Zealand, the Philippines, Portugal, South Africa, Spain, Sweden, Switzerland, the United Kingdom and the United States. Subjects included 588 females (of which 430 were neutered and one was of unknown neuter status) and 637 males (of which 424 were neutered and 6 were chemically castrated)(Table B in S1 File). Dogs that were chemically castrated were not considered for analysing the effect of neutering as we cannot be sure whether they were hormonally equivalent to surgically neutered dogs.

The dogs were of various breeds or mixes, with 729 belonging to a single breed group (i.e. were purebred or had parents from different breeds belonging to the same breed group) and 485 being mixed breeds or crosses from parents of different breed groups. Among dogs from a single breed group 61.0% were neutered, while the proportion of neutered dogs in the mixed breeds was higher at 83.5%. Purebred and mixed-breed dogs also differed in the proportions coming from different sources, as shown in Table C in S1 File. In particular, mixed-breed dogs were more likely to originate from rescues either locally or abroad and were more likely to be former street dogs, while dogs from a single breed group were more likely to originate from a breeder (big/ small), from a private person whose bitch had a litter, to have been rehomed from a private person, or to have been bred and raised by their current owner.

Prevalence of firework fears and age of onset

Based on a Welfare Impaired score of 3 or higher, 639 dogs of the 1225 dogs in the sample (52.2%) were considered to be fearful of fireworks (Table 1).

As 148 of the fearful dogs had been adopted as adults and already showed a fear of fireworks, the age of onset was unknown. In the remaining "fearful" dogs with both current age and age of onset recorded (N = 395), there was a clear trend showing that firework fears tended

Table 1. Distribution of Welfare Impaired score in the population (based on the statement "The overall welfare of my dog is strongly compromised by fireworks": 1 = strongly disagree; 5 = strongly agree).

Welfare Impaired Score	N	% of dogs
1	385	31.43
2	201	16.41
3	115	9.39
4	140	11.43
5	384	31.34
Total	1225	100

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Table 2. Frequency of onset of firework fears in dogs at different ages, relative to the number of dogs having reached the respective ages in the sample (non-fearful dogs and dogs with missing data for age or age of onset are excluded from the dataset).

Age	<1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Number of fearful dogs currently at this age in the sample	-	15	32	46	41	40	51	33	46	28	26	17	11	6	1	2
Number of fearful dogs having reached this age	395	395	380	348	302	261	221	170	137	91	63	37	20	9	3	2
Number of dogs that first developed fear at this age	178	109	84	46	25	22	16	2	2	1	2	1	1	0	0	0
Proportion of dogs that developed fear at this age	0.45	0.28	0.22	0.13	0.08	0.08	0.07	0.01	0.02	0.01	0.03	0.03	0	0	0	0

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to develop at a young age: 45% of owners reported that their dogs developed a fear of fireworks already under one year of age. The second most common age of onset was at two years, followed by three years, and four to six years of age (Table 2). Above six years, very few dogs showed first signs of firework fears. Accordingly, the median age of onset was one year. Table 2 shows the number of dogs in the sample having reached the respective ages at the time of the questionnaire and the numbers and proportions of dogs which experienced an onset of firework fears at the different ages.

Time until recovery

The owners of 11.9% of the fearful dogs reported that their dogs behaved normally immediately after firework exposure, with 21.6% taking up to half an hour to recover and 17.5% taking up to an hour. Recovery took up to three hours in 10.3% and up until the next morning in 12.6%. The dogs' behaviour normalised in the course of the next day in 10.4% and in up to three days also in 10.4%. It took up to one week for recovery in 1.8% of cases, several weeks in 2.3%, and several months in 1.2%, with the latter group including one dog whose behaviour never normalised according to the owner.

Demographic influencing factors

A Kruskal Wallis ANVOA comparing Welfare Impaired scores between male intact, male neutered, female intact and female neutered dogs was highly significant ($N = 1218$, $H = 28.89$, $p<0.0001$). Post-hoc individual comparisons (with adjusted p-values for multiple testing) demonstrated significant differences between male intact and male neutered animals ($z = 3.208$, $p = 0.008$), as well as between female intact and female neutered animals ($z = 3.677$, $p = 0.001$). However, there were no differences between either intact individuals of both sexes ($z = 0.043$, $p = 1.0$) or neutered individuals of both sexes ($z = 0.968$, $p = 1.0$). To summarise, the Welfare Impaired score was significantly higher in neutered dogs of both sexes, but did not show a difference between male and female animals.

The Welfare Impaired score was significantly positively correlated with age, although the strength of the correlation was weak ($r_s = 0.20$, $N = 1095$, $p<0.000001$). There was also a significant positive correlation between the Welfare Impaired score and the dog's age at acquisition, albeit with an even lower correlation coefficient ($N = 1225$, $r_s = 0.119$, $p = 0.00003$). The Welfare Impaired score differed significantly between breed groups (Kruskal Wallis, $N = 1220$, $H = 66.163$, $p<0.0001$; Fig 1). Post-hoc tests (with p-values corrected for multiple testing) indicated that mixed breeds had the highest average Welfare Impaired scores, which differed significantly from companion dogs ($z = 3.53$, $p = 0.032$), molossians ($z = 4.493$, $p = 0.0006$), retrievers ($z = 5.01$, $p = 0.00004$) and hounds ($z = 3.622$ $p = 0.023$). Also herding dogs ranked significantly higher on the Welfare Impaired score than molossians ($z = 3.49$, $p = 0.038$) and retrievers ($z = 3.59$, $p = 0.026$) (Tables C and D in S1 File).

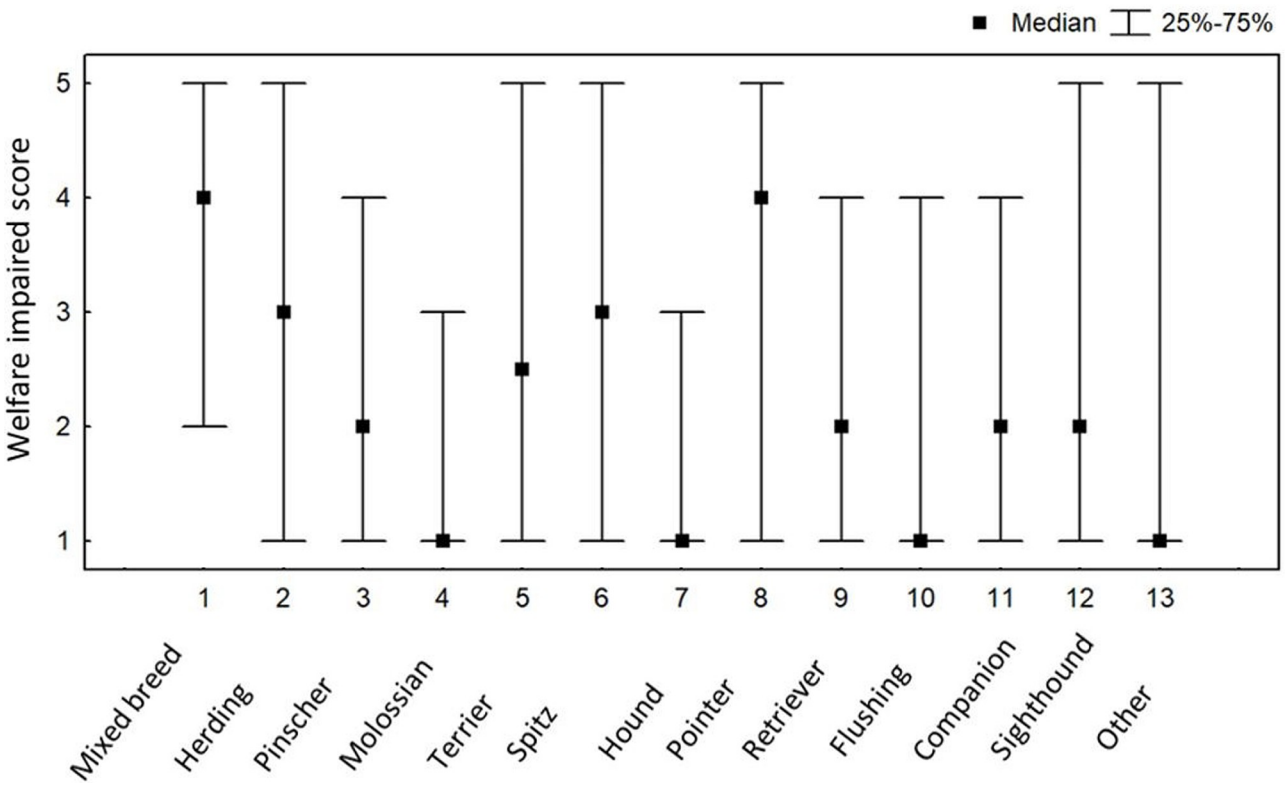

Fig 1. Median Welfare Impaired scores and interquartile ranges for the different breed groups in the sample.

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There was a significant effect of the source of the dog on the Welfare Impaired score (Kruskal Wallis H = 31.715, N = 1042, p = 0.0001; Fig 2). Dogs that were homebred and retained by their breeders scored the lowest on Welfare Impaired during fireworks. Dogs obtained as adults from rescue organisations or shelters, both within the home country and abroad, had the highest scores, and post-hoc tests (with adjusted p-values to correct for multiple comparisons) indicated that this difference was significant in comparison to dogs from small-scale breeders (local rescues: z = 3.483, p = 0.018; rescues abroad: z = 4.207, p = 0.0009)(Tables E and F in S1 File).

Although there appeared to be a trend towards significance for a difference in Welfare Impaired between dogs with and without health problems (N_1 = 820, N_2 = 405, Manny Whitney U test, U = 156252.2, p = 0.093), correction for multiple testing clearly renders this result non-significant.

Results for the binomial model differed for some variables from those obtained in the univariate approach. Thus in the final "best" model, only age, breed group, health problems, and an interaction between health problems and age remained significant predictors of the occurrence of firework fears—whereas source, sex, neuter status and age at acquisition (significant predictors in the univariate analyses on severity of firework fears) were not significant, although source of dog and neuter status were still retained in the best model according to AIC (Table 3; see Tables G-J in S1 File for the full and reduced models). Conversely, the model highlighted a clear effect of health problems on the occurrence of firework fears, which was not apparent in the univariate analysis, probably owing to a significant interaction between health problems and age detected in the model (Table 3; Tables G-J in S1 File). Thus while in

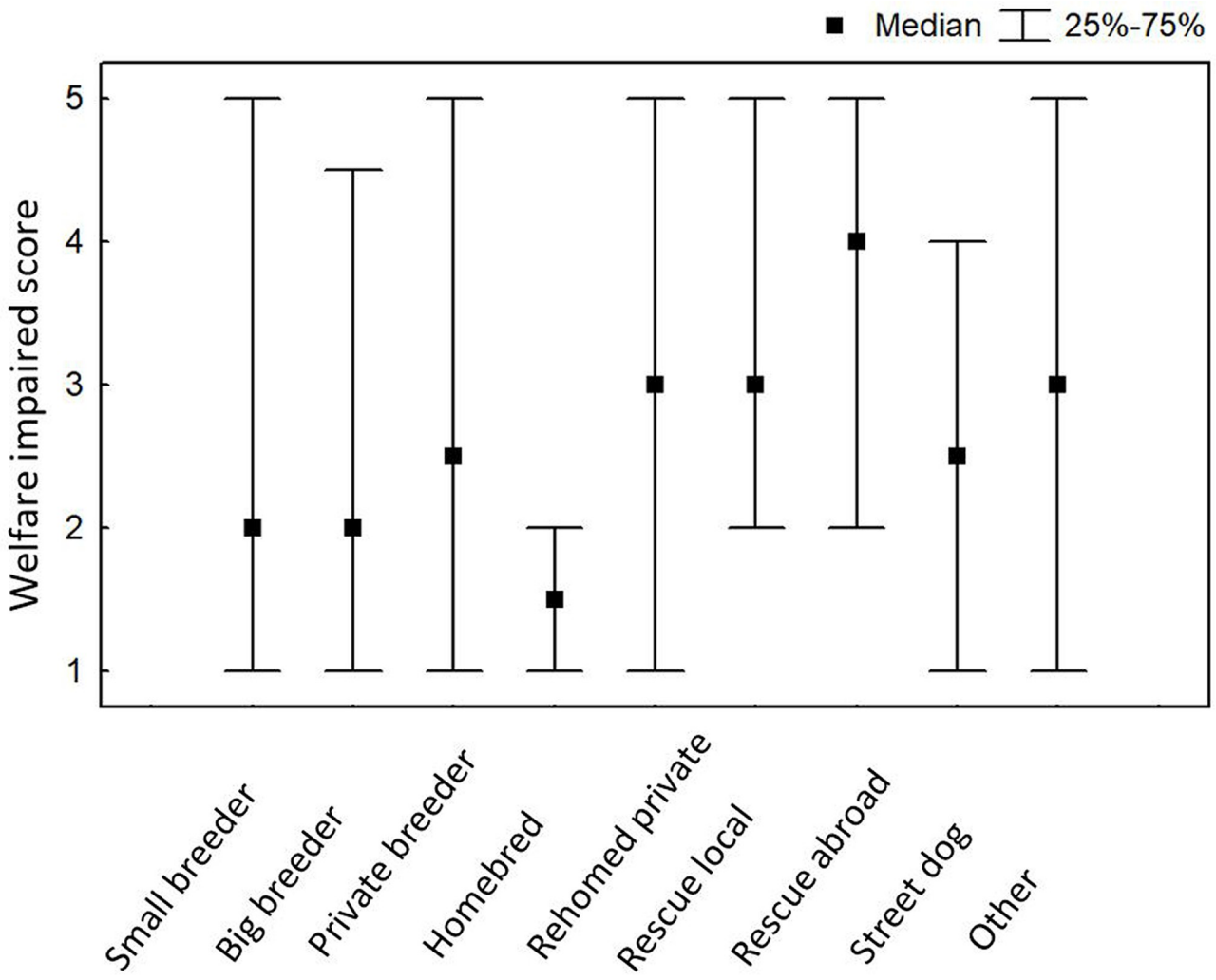

Fig 2. Median Welfare Impaired scores and interquartile ranges for dogs from different origins.

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the younger age groups, dogs affected by health problems had a slightly higher prevalence of firework fears, the reverse was true for the oldest age groups (Fig 3).

Relationship with other behavioural problems

Results of a principal components analysis with varimax rotation on questions relating to behavioural problems. Seven principal components, explaining 83.51% of the variance,

Table 3. Results of the final reduced binomial model testing for the effects of health problems x age, source of dog, sex x neuter status, breed group, and age at acquisition on the occurrence of firework fears in dogs. AIC = 1225.02.

Predictor	Chi^2 Likelihood ratio	Degrees of freedom	p
Health problems	16.265	1	0.00006
Age	35.380	10	0.000000003
Source of dog	12.353	1	0.262
Neuter status	2.464	1	0.117
Breed group	37.083	12	0.0002
Health problems x Age	15.807	1	0.00007

https://doi.org/10.1371/journal.pone.0218150.t003

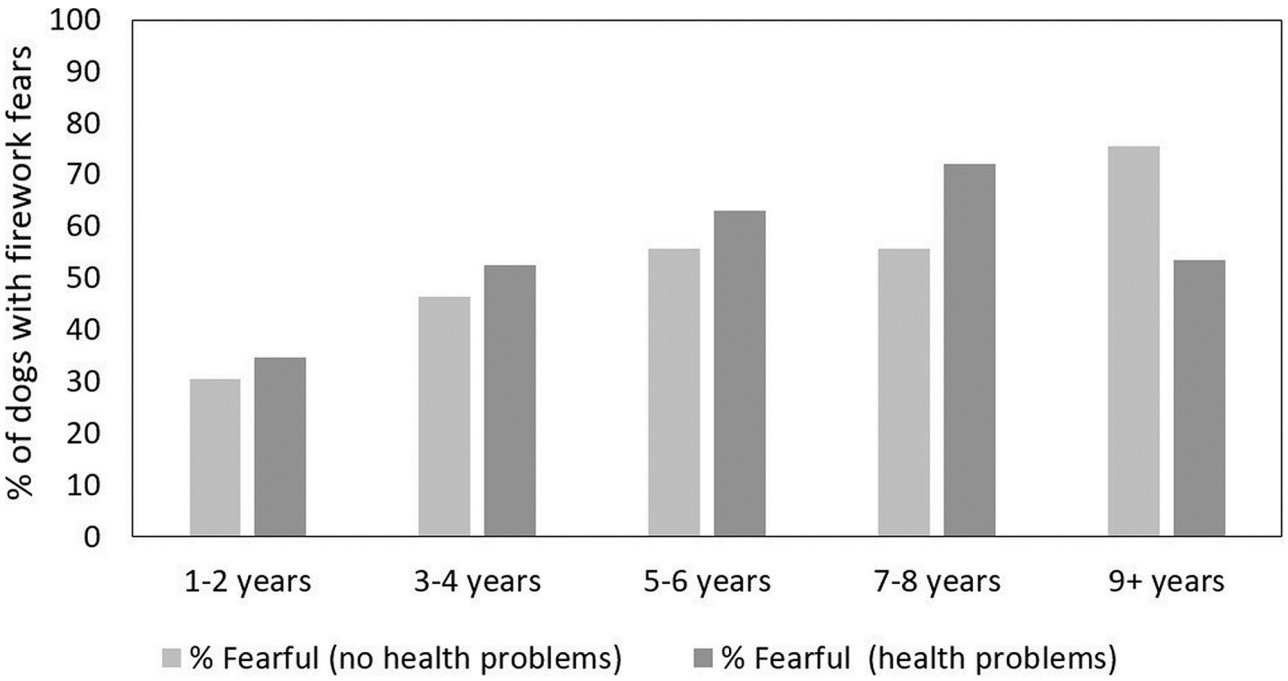

Fig 3. Prevalence of firework fear in dogs of different ages depending on the presence/ absence of health problems.

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were extracted from the 'Behaviour problems' PCA based on biological meaningfulness (Table 4). This indicated that fear of thunder and fear gunshots loaded highly on one component (labelled "Fear of thunder/ gunshots"), while fear of other noises such as shouting and motor noise loaded on a different component ("Fear of shouting/ motor noise"). Fear and aggression towards people loaded highly on one component ("Fear/ Aggression People"), with fear and aggression towards dogs loading on a different component ("Fear/ Aggression Dogs"). In contrast, the component "Resource guarding" encompassed resource guarding behaviour towards both humans and dogs. Two further components were almost entirely composed of single variables, namely "Separation problems" and "Hyperactivity", respectively. There were no cross-loadings of variables on different components, considering a cut-off point of 0.4.

The Welfare Impaired score during fireworks was highly significantly positively correlated with the principal component encompassing fear of thunder and gunshots ($r_s = 0.719$, $N = 1225$, $p<0.0000001$). To a lesser extent, it was also associated with a fear of other noises such as motor noise and shouting ($r_s = 0.136$, $N = 1225$, $p = 0.000002$). Although separation related problems have been suggested as a frequent co-morbidity with noise fears [32], in this sample there was no correlation with impaired welfare during fireworks ($r_s = 0.0003$, $N = 1225$, $p = 0.666$). There was also no relationship of the Welfare Impaired score with Fear/ Aggression towards people ($r_s = 0.027$, $N = 1225$, $p = 0.346$), Fear/ Aggression towards dogs ($r_s = 0.0003$, $N = 1225$, $p = 0.991$), Resource guarding against people and dogs ($r_s = -0.018$, $N = 1225$, $p = 0.514$), and Hyperactivity ($r_s = -0.045$, $N = 1225$, $p = 0.119$).

Advice sought. 47.51% of owners in the total sample and 69.79% of owners of dogs with firework fears (Welfare impaired scores of 3 and above) had sought some form of advice. 36.14% of owners of fearful dogs had consulted a veterinarian, 49.76% a trainer, 46.64% the internet, 33.49% a book, 25.66% a friend, and 3.23% other sources.

Table 4. Results of a PCA on variables referring to behavioural problems other than firework fears, with varimax rotation. Loadings >0.4 are bolded.

Variables	Components						
	Fear of thunder/ gunshots	Fear/ Aggression People	Fear/ Aggression Dogs	Resource guarding	Fear of shouting/ motor noise	Separation problems	Hyperactivity
Fear of dogs	.064	.244	**.829**	.016	.177	.118	-.041
Aggression towards dogs	.046	.142	**.852**	.273	-.021	-.036	.074
Fear of people	.069	**.837**	.167	.018	.248	.127	-.005
Aggression towards people	.048	**.841**	.212	.229	.011	-.018	.032
Separation problems	.057	.082	.062	.105	.070	**.971**	.068
Resource guarding (dogs)	.020	-.041	.290	**.814**	.048	.102	.061
Hyperactivity	.001	.019	.024	.070	.043	.065	**.990**
Fear of thunder	**.919**	.021	.039	.007	.160	.024	-.040
Fear of gunshots	**.912**	.081	.055	.036	.149	.049	.038
Fear of motor noise	.387	.088	.095	.052	**.725**	-.055	.085
Fear of shouting	.069	.144	.057	.042	**.882**	.122	-.014
Resource guarding (people)	.026	.286	-.001	**.824**	.043	.027	.027
Eigenvalue	*3.31*	*1.891*	*1.16*	*1.07*	*0.91*	*0.863*	*0.817*
Variance %	*27.58*	*15.75*	*9.67*	*8.92*	*7.58*	*7.19*	*6.81*
Cumulative variance %	*27.58*	*43.34*	*53.01*	*61.93*	*69.51*	*76.70*	*83.51*

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Fear progression. As shown in Table 5, both improvement and deterioration of firework fears were frequently reported, with great improvement reported for over 10% of dogs, almost one-third of dogs tending to have improved, one-third of dogs with no change, just under one fifth where the fear tended to deteriorate and stark deterioration reported for 8.5%.

When only dogs were included whose owners had not sought advice of any kind and did not indicate in the comments that they were behaviour specialists such as trainers or vets themselves, slightly less improvement was reported than in the full sample, but also less deterioration, with about half the dogs remaining unchanged (Table 6).

Prevention of firework fears through training. Overall, owners of 530 dogs (43.3%) had attempted some training to prevent or treat firework fears in their dogs. Regarding preventative training (before the onset of any firework fears), the owners of 228 dogs (18.8%) started to do so when their dog was a puppy and 82 (6.8%) when their dog was an adult. 74.4% did not perform any preventative training with their dogs.

The analyses demonstrated a large protective effect of training before dogs react fearfully to fireworks (Kruskal Wallis H = 92.663, N = 1213, $p<0.0001$). The median Welfare Impaired

Table 5. Reported progression of firework fears in dogs affected by firework fears.

Owners' rating of fear progression	N	%
The fear has improved greatly	69	10.88
The fear tends to have improved	180	28.39
The fear has remained the same	213	33.60
The fear tends to have become worse	118	18.61
The fear has become much worse	54	8.52
Total	**664**	**100**

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Table 6. Reported progression of firework fears in dogs with firework fears whose owners did not seek any advice to address the problem.

Owners' rating of fear progression	N	%
The fear has improved greatly	12	7.64
The fear tends to have improved	35	22.29
The fear has remained the same	78	49.68
The fear tends to have become worse	21	13.38
The fear has become much worse	11	7.01
Total	**157**	**100**

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score was 1 (lowest possible score) in dogs having received training as a puppy, 2 in dogs having received training as an adult, and 4 (second highest score) in dogs with no training before the onset of any firework fears (Fig 4). Although the beneficial effect of training appeared to be most pronounced when training was commenced when the dog was still a puppy, post-hoc tests (two-sided significance levels with Bonferroni adjustment) indicated no significant difference in welfare scores between dogs having received training as puppies and as adults (prior to

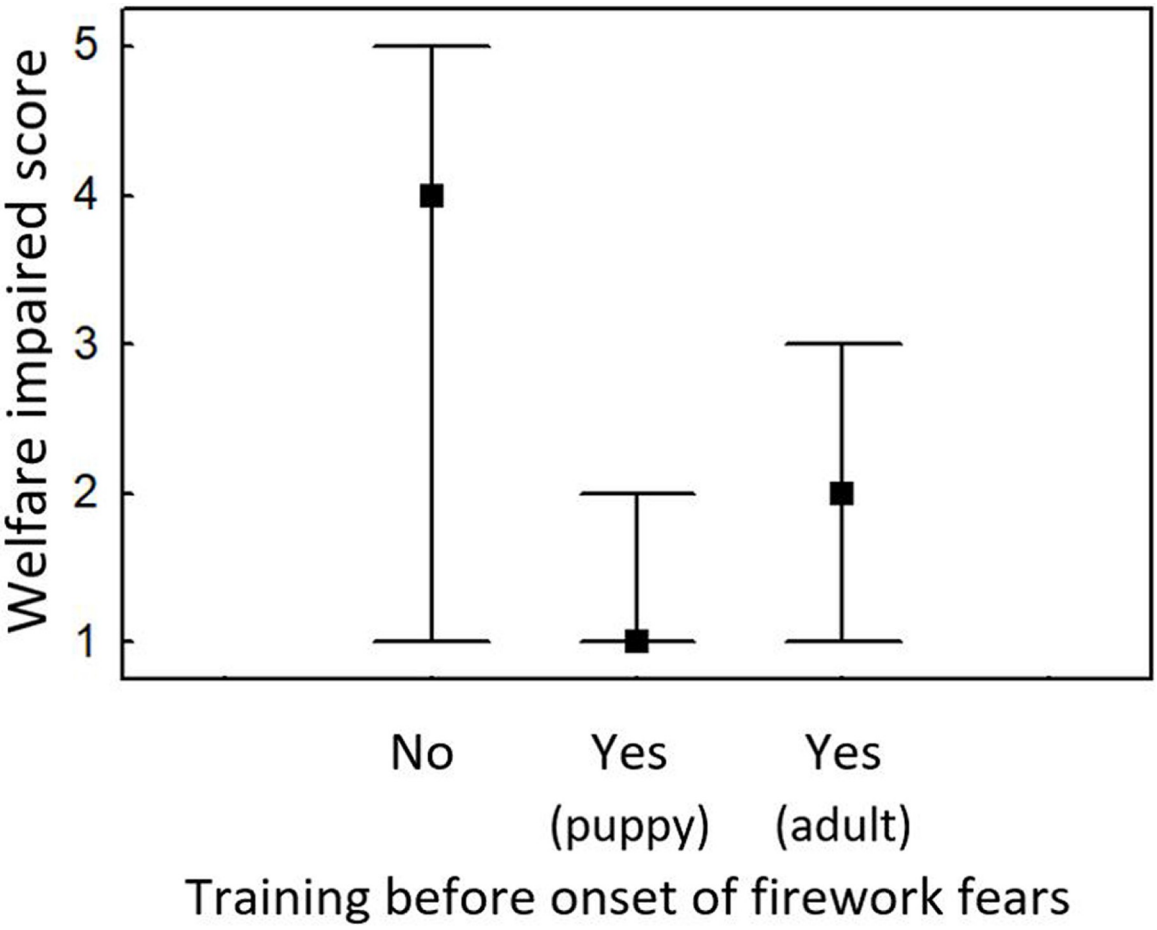

Fig 4. Median Welfare Impaired scores and interquartile ranges for dogs whose owners performed training against firework fears with them either as puppies or adults before the onset of any noise fears versus dogs who had received no such preventative training.

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showing any fear of fireworks) (z = 1.892, p = 0.175). Both groups had highly significantly lower Welfare Impaired scores than dogs who received no training or whose owners commenced training only once the dogs already showed fearfulness (training as puppies: z = 8.938, p<0.000001, training as adults: z = 3.662, p = 0.0008).

Effect of training on fear progression in fearful dogs. Within those dogs experiencing impaired welfare during fireworks (Welfare Impaired scores of 3 and above), the progression of firework fears was compared for dogs whose owners had attempted training against firework fears compared to no such training. The results indicated that the progression of firework fears was highly significantly more favourable in those dogs receiving training (Mann Whitney U = 38853.5, N = 632, p = 0.00001), with a median progression score of 2 ("tended to have improved") compared to dogs receiving no training (median progression score of 3 –"no change")(S1 Fig). The proportion of dogs receiving anxiolytic medication did not differ significantly between fearful dogs that received behavioural training (93/324; 28.7%) and those that did not (73/313; 23.3%, $Chi^2 = 2.39$, p = 0.122).

Discussion

In line with past studies, the results indicate that fear of fireworks is highly prevalent in the pet dog population, with 52.16% in the sample at least partly affected, and almost one-third of dogs receiving the highest possible severity score. Previous studies found a prevalence of noise fears ranging from 23% to 49% [1–3]. While the advertisement for the current survey explicitly stated that dogs both with and without noise fears were of interest, it is conceivable that owners with affected dogs might have a higher motivation to participate. Still, even if prevalence was somewhat over-estimated, the reported prevalence is consistently high also in previous studies [1–3]. The majority of fearful dogs (almost 75%) had recovered by the next morning after experiencing a firework; nevertheless it took between three days to a week for full recovery in 12% of dogs, and a small proportion of dogs even took several weeks or even months to recover, with one dog's behaviour reported to never normalise. Thus, fear of fireworks is a significant factor affecting canine welfare, both in absolute number of affected animals and duration of symptoms.

While no sex differences in the severity of firework fears were found, a significant effect of neutering was found in both males and females, with neutered dogs showing a greater fear of fireworks than intact dogs. This relationship appeared, however, only when analysing the effect of neutering separately as a single variable with nonparametric statistics. In contrast, when testing the effect of neutering in combination with other predictors on the presence/ absence of fireworks, neutering had no significant effect, and only the effects of breed group, age, health problems, and an interaction between health problems and age remained significant.

This may indicate that neutering per se may not actually be causative for a higher fear severity (or prevalence, as in [1,3]), but it just may be coincidental with other factors predisposing to firework fears, and this could even explain contrasting results from previous studies: Storengen and Lingaas [1] reported that neutered dogs were more likely to be affected by noise fears (odds ratio: 1.73), whereas Blackwell et al. [2] found no effect of neutering. The current study used a Type 3 model, meaning that all other variables were accounted for when calculating the effect of a given predictor (c.f. [33]). The statistical methods are similar to those used by Blackwell et al. [2], who likewise included neuter status in a model with multiple predictors. On the other hand, the reported higher likelihood of noise fears in neutered dogs in Storengen and Lingaas [1] was based on the relative frequency of dogs fearful of noises in the neutered vs the unneutered population. Also Tiira et al. [3] performed non-parametric tests on the effect of neuter status on behavioural signs shown during noise exposure. As such, other possible

influencing factors were not taken into account. A significant effect of neutering on noise fears was found in Tiira & Lohi [34], but when only noise sensitive dogs without comorbid fears (separation related problems; fear towards strangers or in new situations) were included, this effect disappeared. Thus, this effect might similarly be driven by underlying factors (such as early socialization, which became significant in the latter sample) that predisposed dogs to a range of behavioural problems [34].

Clearly, there is still a lack of research on the behavioural effects of neutering (and at what age) in dogs—but the current study points to the importance of considering factors beyond mere correlations, with causative factors possibly only happening to coincide with neutering. Notably, the proportion of neutered individuals in our study was substantially higher in the mixed breeds (83.51%) than in dogs from a single FCI group (61.04%). As can be seen in Table B in S1 File, the proportion of neutered dogs is also considerably greater in dogs originating from rescues (locally or abroad), dogs that were former street dogs, were rehomed privately, or came from another source (subsumed as "other"), compared to dogs from big breeders (5 or more litters per year), small breeders (<5 litters per year), private persons whose bitch had had a litter, or dogs that were bred and kept by their current owners. Thus, the likelihood of neutering increased with other risk factors for behavioural problems such as being of mixed breed, originating from a shelter, and an older age at acquisition. Regarding the question of effects of neutering on behavioural problems, longitudinal case control studies are needed to disentangle the effects of the surgical intervention from other potential risk factors frequently associated with neutering.

Similarly, the proportion of mixed breeds compared to purebreds was much higher in dogs from rescues (local and abroad) and street dogs compared to dogs from breeders. One large scale study (on over 15,000 dogs) has compared characteristics of mixed-breed and purebred dogs [35]. The study found that mixed-breed dogs were more often neutered and were on average adopted at a later age than purebreds [35]. Differences in owners' demographics included that owners of mixed breeds were less educated, younger and had less experience with dogs. Mixed breeds received less training, were more likely to be kept only indoors, and as single dogs, although there was no difference in the attitude and commitment of the owners, except that time spent walking was higher for the mixed-breeds than for the purebreds [35]. The incidence of problematic behaviours was significantly higher in the mixed breeds, even after controlling for the distribution of the demographic and dog keeping factors [35]. The current study did not investigate whether the owners' demographic and dog keeping characteristics differed between mixed and purebreds in the same way as in [35], but if the patterns parallel these from [35], it is possible that besides likely differences in socialisation, the lower age, education and experience with dogs of owners of mixed breeds could contribute to the observed difference in firework fear between mixed breeds and dogs from a single breed group.

Similar to neutering, origin and age at acquisition (which had strong univariate effects) were no longer significantly associated with the occurrence of firework fears in the binomial models. Nonetheless, although the statistics point to being of mixed breed as the decisive factor, given the association between the predictors breed group, origin, age at acquisition and neutering, the data do not allow clear conclusions about the driving factor behind possible differences in fearfulness, and all of them may, in fact, contribute. Except for puppies adopted too early before 8 weeks of age [36,37], older ages of acquisition were found to be associated with more behaviour problems [38,39]. Moreover, the early environment is particularly important in shaping dogs' behaviour [40–42], even beyond the primary period of socialization [43,44]. As also pointed out by Pierantoni et al. [35], it is likely that dogs from shelters or picked up as strays, which had a much larger proportion of mixed breeds than dogs obtained from breeders,

had less favourable environmental conditions during their early development. A combination of these factors may contribute to the higher incidence and severity of firework fears in mixed-breed dogs, and this might explain why univariate, but not multivariate analyses indicated significant effects of neutering, source and age at acquisition.

While mixed breeds scored the highest on the Welfare impaired score, significant differences also occurred between some breed groups. In particular, molossians, retrievers, flushing dogs and companion dogs had lower Welfare impaired scores, while herding dogs had the highest Welfare impaired scores after the group of mixed breeds. Other studies similarly found breed (group) differences, although results are not directly comparable given different breed (group) classifications [1–3].

The current study confirmed the finding by Blackwell et al. [2] that dogs that were home-bred were least affected by noise fears. Perhaps breeders are particularly careful when socialising puppies they are intending to keep, or—having the first choice of the litter—they were most likely to keep the temperamentally most sound puppy. It is also possible that the owners who bred their own dog were especially committed, or perhaps the puppies benefitted from the older dogs in the household, with most breeders having more than one dog. Blackwell et al. [2] also suggested that breeders might be less willing to admit to the occurrence of behaviour problems in their breeding adults, or that dogs bred by their owners benefitted from remaining in the same environment they were born and socialised in.

An effect of health problems was only significant in the multivariate, but not the univariate analysis, reflecting a significant interaction between health problems and age. There was a clear increase in prevalence of firework fears with increasing age in the healthy dogs until ten years, but a decrease in dogs 11 years or older. In dogs with health problems, firework fears increased until the age of eight years and decreased in dogs nine years and older. Comparing the presence of firework fears in the two groups (dogs with/ without health problems), firework fears were moderately more common in dogs with health problems compared to healthy dogs until the age of eight years. Conversely, from the age of nine years, the incidence of firework fears was lower in dogs with health problems. Perhaps the data were less reliable for the older dogs due to the smaller sample sizes. It is possible that the proportion of dogs with health problems increased with age, but at the same time, loss of hearing [45], especially in the older dogs with health problems, may have attenuated some noise fears (c.f. [2]). Maybe those dogs that had health problems at an earlier age also experienced other age-related declines such as loss of hearing sooner. Thus, while health problems may contribute to firework fears, this effect did not appear to be strong in the current sample.

Other potentially relevant factors for the development of noise fears that were not investigated in the current survey include early experiences affecting stress resilience [34,46] or the chance to habituate to noises depending on the season of birth (c.f. [42]), owners' management methods (e.g. providing a hiding place; for more details see [47]), and the amount of exercise [34]. Of interest, the latter was the most important environmental factor associated with noise fears in Tiira and Lohi [34]. While exercise per se might have increased dogs' stress resilience, it is also a possibility that those owners who exercised their dogs more might be more committed and more likely to engage in (preventative) training with their dogs. Thus, Tiira and Lohi [34] found that, among other things, amount of exercise was associated with the time the owner spent on activities with the dog [34]. As amount of exercise was not evaluated in the current study, the effects of exercise and potentially associated variables such as preventative training on the severity of noise fears cannot be disentangled. However, as there is no reason to assume that owners changed their exercise habits due to their dog becoming fearful of fireworks, the fact that not only the Welfare impaired score, but also the Fear progression score

was significantly more favourable in dogs that received behavioural training supports the notion that training itself had beneficial effects.

Moreover, the observed favourable effect of training on fear progression cannot be explained by concurrent use of medication, as the proportion of fearful dogs that received medication did not differ significantly between those that received behavioural training and those that did not. Other calming products were not considered relevant, since the survey indicated that the effectiveness of pheromones, nutraceuticals, herbal products, essential oils, homeopathic remedies and Bach flowers was not higher than would be expected based on a placebo effect (see [47] for details).

Regarding comorbidities with other behavioural problems, the current results confirm previous findings regarding the strong co-occurrence of firework fears with fears of thunder and gunshots, but a lower relationship with fears of other noises [2,3]. Thus, fear of firework, gunshots and thunder does not necessarily seem to coincide with sensitivity to other types of noises. As in [2], no relationship with separation related problems was detected, although some other studies confirmed Overall et al.'s [12,32] notion that noise fears and separation related problems frequently co-occur [1,3]. In my sample, no other behavioural problems were associated with firework fears, indicating that noise fears are a separate phenotype from social fears (dogs/ humans), and are also unrelated to other behaviour problems including resource guarding and hyperactivity. I did, however, not ask about fear in new situations, which was related to noise fears in Storengen et al. [1], and was also included in a score for "Fearfulness" (together with fear toward unfamiliar people) in Tiira & Lohi [3]. Also, the cited studies did not use a graded score but presence or absence of noise fears. It is thus a possibility that, to some extent, this may account for divergent results.

In the current survey, the great majority of fearful dogs showed signs of noise fears from a very early age– 45% even developed a fear of fireworks below the age of one year. Given that the age group of dogs having reached one year was the largest in the sample, data from this age group are also likely to be most reliable. The second largest group of dogs developed noise fears at the age of one year, followed by two years and three years, respectively. Very few dogs showed first signs of noise fears after the age of six years, although a new onset was reported up to the age of 12 years. Thus, the older the dog, the less likely it was to develop noise fears if it had not acquired such a fear previously.

The very early onset (median one year), as well as the observed breed differences, are suggestive of a significant genetic contribution to the development of noise fears. The median age of onset was slightly higher in Tiira et al. [3] at two years. Still, also in their sample, half of the affected dogs had developed a fear of noises in the first two years of life [3]. One possible difference between the study results may lie in the form of questions. In the current study, the question was formulated as "At what age did fear of fireworks first become apparent in your dog?" This does not necessarily mean that the fear would have fully developed, and results might have been different if I had asked for manifested fears. Thus, it is likely that affected dogs do show signs from an early age, but by what Overall calls "social maturity" (at around 20 months of age in medium-sized dogs), these may have become manifest [12].

It would be expected for firework fears to increase with age, as the likelihood of encountering fear-eliciting noises inevitably increases over time [2]. Furthermore, sensitisation to and generalisation of noises may occur [2]. In line with this, although in most dogs, noise fears were acquired at an early age, the prevalence [1–3] and/ or average severity [4] increases with age in the population (up to a certain age), both in my sample and the cited studies. Unfortunately prevalence and severity cannot be clearly distinguished here, since if a higher number of dogs are affected by noise fears as they age (as would be expected), then the average severity

score in the population would also increase, although this does not necessarily mean that individual fearful dogs show an increase in severity.

Therefore owners were also asked how their dogs' fear of fireworks had changed in recent years. The results indicated that firework fears do not have to be a one-way road. Indeed, approximately equal numbers of respondents indicated that their dogs' fear had improved, remained the same and deteriorated, respectively. Almost 11% even reported a great improvement, with 28% indicating some improvement. No change was noted in one-third of the dogs, while the fear tended to have become worse, or had become much worse in 18% and 8% of the dogs, respectively.

The relatively high proportion of improvement is at first sight surprising. It may reflect the high proportion of owners in the current study who had sought (professional) advice—with almost half of the owners of affected dogs having consulted a trainer and more than one-third a veterinarian. On the other hand, even when including only dogs whose owners had not sought any advice, an improvement was reported for 30%, no change for 50%, and deterioration for 20%. This indicates that firework fears do not necessarily need to become worse over time. Also Blackwell et al. [2] report that a spontaneous recovery occurred in a small number of cases; however, for about half the cases this appeared to be due to the onset of deafness. Similarly, loss of hearing most likely explains the lower severity of firework fears in the oldest age groups in the current study.

Overall, 45% of owners (and almost 70% of owners of fearful dogs) reported having sought advice (which besides trainers and vets included the internet, books or friends). This is in stark contrast to Dale et al. [4] where only 15.8% had sought any advice at all. Also in the sample by Blackwell and colleagues [2], only 29% had sought any help from vets, behaviourists, trainers, friends or other sources. This difference may reflect raised awareness of this issue over time, or may be an issue of the sampling. It cannot be ruled out that owners with a particularly high interest in dog behaviour were more likely to come across the survey invitation, which was spread in dog-related Facebook groups, while the questionnaires in the other studies were spread to a less self-selected population (contacts via veterinary practices, dog shows, agricultural or horse shows, dog walkers and other locations, [2]; Auckland SPCA's Animals Voice magazine and veterinary clinics [4]). On the other hand, both of these studies used postal surveys—requiring the owners to not only fill in the questionnaire but post it to them as well—and as such a higher effort than filing in the questionnaire online as in my study [2,4]. Of interest, apart from this difference, results in the current survey regarding demographic influencing factors were remarkably similar to those obtained by Blackwell et al. [2].

The high proportion of owners (over 40%) who made the effort of training to address (potential) noise fears in their dogs may be another explanation for the high frequency of cases in which an improvement was noted. One-quarter of respondents had even commenced training before their dog was affected by any firework fears. This preventative training was highly successful: the median Welfare impaired score for dogs having received training as puppies was 1, meaning that the owners did not consider their dogs' welfare to be impaired by fireworks at all. But also in adults, preventative training was useful, leading to a median Welfare impaired score of 2, compared to a score of 4 in dogs that received no preventative training.

Targeted questions indicated that owners found ad-hoc counter-conditioning (providing a high-value incentive after the occurrence of noises) and relaxation training (training dogs to relax on cue) to be the most effective training techniques for alleviating firework fears (effective in more than two-thirds of cases)[47]). Thus, in a large number of dogs, prevention of noise fears by early training seems possible, and this would be a valuable piece of advice that veterinarians could give to new puppy owners when seeing the puppies for their first vaccinations, or trainers holding puppy classes. If more dog owners adopted this strategy, there would be

potential to greatly reduce the incidence and/ or severity of firework fears in dogs, thus significantly improving their welfare.

Conclusions

Older age and being a mixed breed appear to constitute the most important risk factors for firework fears in dogs. The latter might be explained by underlying differences between mixed-breed dogs and purebreds, such as in their socialisation experiences. Similarly, while severity of firework fears appears higher in neutered dogs in univariate analyses, this effect might be driven by other underlying factors, and it was no longer significant when controlling for other factors. Firework fears are highly correlated with fears of gunshots and thunder, and to a low extent with fears of other noises, but not with any other behavioural problems. Both improvement and deterioration of firework fears were frequently reported. While an early age of onset and breed differences in firework fears point to a strong genetic contribution, prevention is nonetheless possible, and training puppies as well as adult dogs to associate the noise with positive stimuli appears to be highly effective in preventing a later development of firework fears.

Supporting information

S1 File. (**Table A**) Relevant questions from the questionnaire survey. (**Table B**) Distribution of sex, neuter status and breed group (pure/ mixed)–where known—in dogs from different origins. (**Table C**) z-values for post-hoc tests of differences in Welfare Impaired scores in different breed groups. (**Table D**) p-values for post-hoc tests (adjusted for multiple testing) of differences in Welfare Impaired scores in different breed groups. (**Table E**) z-values for post-hoc tests comparing Welfare Impaired scores in dogs from different origins. (**Table F**) p-values for post-hoc tests (adjusted for multiple testing) comparing Welfare Impaired scores in dogs from different origins. (**Table G**) Results of a binomial model testing for the effects of health problems x age, source of dog, sex x neuter status, breed group, and age at acquisition on the occurrence of firework fears in dogs. Full model (AIC = 1229.63). (**Table H**) Results of a binomial model testing for the effects of health problems x age, source of dog, sex x neuter status and breed group on the occurrence of firework fears in dogs. Second model reduction (AIC = 1227.65). (**Table I**) Results of a binomial model testing for the effects of health problems x age, source of dog, sex, neuter status and breed group on the occurrence of firework fears in dogs. Third model reduction (AIC = 1225.95). (**Table J**) Results of a binomial model testing for the effects of health problems x age, neuter status and breed group on the occurrence of firework fears in dogs. Fifth model reduction (AIC = 1420.04 → higher than for the fourth model reduction presented in the manuscript as final reduced model).
(DOCX)

S1 Fig. Median fear progression scores and interquartile ranges in fearful dogs (Welfare Impaired score $\geq$3) that had received behavioural training against firework fears vs no training.
(TIF)

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Author Contributions

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References

1. Storengen LM, Lingaas F. Noise sensitivity in 17 dog breeds: Prevalence, breed risk and correlation with fear in other situations. Appl Anim Behav Sci. Elsevier; 2015; 171: 152–160.
2. Blackwell EJ, Bradshaw JWS, Casey RA. Fear responses to noises in domestic dogs: Prevalence, risk factors and co-occurrence with other fear related behaviour. Appl Anim Behav Sci. Elsevier; 2013; 145: 15–25.
3. Tiira K, Sulkama S, Lohi H. Prevalence, comorbidity, and behavioral variation in canine anxiety. J Vet Behav Clin Appl Res. Elsevier; 2016; 16: 36–44.
4. Dale AR, Walker JK, Farnworth MJ, Morrissey SV, Waran NK. A survey of owners' perceptions of fear of fireworks in a sample of dogs and cats in New Zealand. N Z Vet J. Taylor & Francis; 2010; 58: 286–291.
5. Seksel K, Lindeman MJ. Use of clomipramine in treatment of obsessive-compulsive disorder, separation anxiety and noise phobia in dogs: a preliminary, clinical study. Aust Vet J. Wiley Online Library; 2001; 79: 252–256.
6. Levine ED, Mills DS. Long-term follow-up of the efficacy of a behavioural treatment programme for dogs with firework fears. Vet Rec. British Medical Journal Publishing Group; 2008; 162: 657–9.
7. Korpivaara M, Laapas K, Huhtinen M, Schöning B, Overall K. Dexmedetomidine oromucosal gel for noise-associated acute anxiety and fear in dogs—a randomised, double-blind, placebo-controlled clinical study. Vet Rec. 2017; 180: 356. https://doi.org/10.1136/vr.104045 PMID: 28213531
8. Landsberg G, Beck A, Lopez A, Deniaud M, Araujo J, Milgram N. Dog-appeasing pheromone collars reduce sound-induced fear and anxiety in beagle dogs: a placebo-controlled study. Vet Rec. BMJ Publishing Group; 2015; 177: 260.
9. Pekkin A-M, Hänninen L, Tiira K, Koskela A, Pöytäkangas M, Lohi H, et al. The effect of a pressure vest on the behaviour, salivary cortisol and urine oxytocin of noise phobic dogs in a controlled test. Appl Anim Behav Sci. Elsevier; 2016; 185: 86–94.
10. Cracknell NR, Mills DS. A double-blind placebo-controlled study into the efficacy of a homeopathic remedy for fear of firework noises in the dog (*Canis familiaris*). Vet J. Elsevier; 2008; 177: 80–88.
11. McPeake K, Affenzeller N, Mills D, others. Noise sensitivities in dogs: a new licensed treatment option. Vet Rec. BMJ Publishing Group for British Veterinary Association; 2017; 180: 353–355.
12. Overall KL, Dunham AE, Juarbe-Diaz S V. Phenotypic determination of noise reactivity in 3 breeds of working dogs: A cautionary tale of age, breed, behavioral assessment, and genetics. J Vet Behav Clin Appl Res. Elsevier; 2016; 16: 113–125.
13. Sherman BL, Mills DS. Canine anxieties and phobias: an update on separation anxiety and noise aversions. Vet Clin North Am Small Anim Pract. Elsevier; 2008; 38: 1081–1106.
14. Perusini JN, Fanselow MS. Neurobehavioral perspectives on the distinction between fear and anxiety. Learn Mem. Cold Spring Harbor Lab; 2015; 22: 417–425.
15. Bellamy KKL, Storengen LM, Handegård KW, Arnet EF, Prestrud KW, Overall KL, et al. DRD2 is associated with fear in some dog breeds. J Vet Behav. Elsevier; 2018; 27: 67–73.
16. Sarviaho R, Hakosalo O, Tiira K, Sulkama S, Salmela E, Hytönen MK, et al. Two novel genomic regions associated with fearfulness in dogs overlap human neuropsychiatric loci. Transl Psychiatry. Nature Publishing Group; 2019; 9: 18.
17. Lopes Fagundes AL, Hewison L, McPeake KJ, Zulch H, Mills DS. Noise sensitivities in Dogs: An exploration of signs in Dogs with and without Musculoskeletal Pain Using Qualitative content Analysis. Front Vet Sci. Frontiers; 2018; 5: 17.

18. Beerda B, Schilder MBH, van Hooff JA, de Vries HW, Mol JA. Behavioural, saliva cortisol and heart rate responses to different types of stimuli in dogs. Appl Anim Behav Sci. Elsevier; 1998; 58: 365–381.
19. Beerda B, Schilder MBH, van Hooff JA, de Vries HW. Manifestations of chronic and acute stress in dogs. Appl Anim Behav Sci. Elsevier; 1997; 52: 307–319.
20. Cracknell NR, Mills DS. An evaluation of owner expectation on apparent treatment effect in a blinded comparison of 2 homeopathic remedies for firework noise sensitivity in dogs. J Vet Behav Clin Appl Res. Elsevier Inc; 2011; 6: 21–30. https://doi.org/10.1016/j.jveb.2010.07.004
21. Levine ED, Ramos D, Mills DS. A prospective study of two self-help CD based desensitization and counter-conditioning programmes with the use of Dog Appeasing Pheromone for the treatment of firework fears in dogs (*Canis familiaris*). Appl Anim Behav Sci. Elsevier; 2007; 105: 311–329.
22. Riemer S, Müller C, Virányi Z, Huber L, Range F. Individual and group level trajectories of behavioural development in Border collies. Appl Anim Behav Sci. 2016; 180: 78–86. https://doi.org/10.1016/j.applanim.2016.04.021 PMID: 28184101
23. Sheppard G, Mills DS. Evaluation of dog-appeasing pheromone as a potential treatment for dogs fearful of fireworks. Vet Rec J Br Vet Assoc. 2003; 152: 432–436.
24. Mills DS, Estelles MG, Coleshaw PH, Shorthouse C. Retrospective analysis of the treatment of firework fears in dogs. Vet Rec. British Medical Journal Publishing Group; 2003; 153: 561–562.
25. Chaloupková H, Svobodová I, Vápeník P, Bartoš L. Increased resistance to sudden noise by audio stimulation during early ontogeny in German shepherd puppies. PLoS One. Public Library of Science; 2018; 13: e0196553.
26. Alves JC, Santos A, Lopes B, Jorge P. Effect of auditory stimulation during early development in puppy testing of future police working dogs. Top Companion Anim Med. Elsevier; 2018; 33: 100–104.
27. Rooney NJ, Clark CCA, Casey RA. Minimizing fear and anxiety in working dogs: a review. J Vet Behav. Elsevier; 2016; 16: 53–64.
28. Siegel S, Castellan N. Nonparametric Statistics for the Behavioral Sciences. second edi. New York. McGraw-Hill; 1988.
29. Ananth C V, Kleinbaum DG. Regression models for ordinal responses: a review of methods and applications. Int J Epidemiol. 1997; 26: 1323–1333. https://doi.org/10.1093/ije/26.6.1323 PMID: 9447413
30. Morrow-Howell N, Proctor E. The use of logistic regression in social work research. J Soc Serv Res. Taylor & Francis; 1993; 16: 87–104.
31. Jolliffe IT, Cadima J. Principal component analysis: a review and recent developments. Philos Trans R Soc A Math Phys Eng Sci. The Royal Society Publishing; 2016; 374: 20150202.
32. Overall KL, Dunham AE, Frank D. Frequency of nonspecific clinical signs in dogs with separation anxiety, thunderstorm phobia, and noise phobia, alone or in combination. J Am Vet Med Assoc. Am Vet Med Assoc; 2001; 219: 467–473.
33. Olsson U. Generalized linear models. An Appl approach Studentlitteratur, Lund. 2002;18.
34. Tiira K, Lohi H. Early life experiences and exercise associate with canine anxieties. PLoS One. Public Library of Science; 2015; 10: e0141907.
35. Turcsán B, Miklósi Á, Kubinyi E. Owner perceived differences between mixed-breed and purebred dogs. PLoS One. Public Library of Science; 2017; 12: e0172720.
36. Pierantoni L, Albertini M, Pirrone F. Prevalence of owner-reported behaviours in dogs separated from the litter at two different ages. Vet Rec. British Medical Journal Publishing Group; 2011; 169: vr.d4967.
37. Slabbert JM, Rasa OA. The effect of early separation from the mother on pups in bonding to humans and pup health. J S Afr Vet Assoc. 1993; 64: 4–8. PMID: 7802733
38. McGreevy PD, Masters AM. Risk factors for separation-related distress and feed-related aggression in dogs: additional findings from a survey of Australian dog owners. Appl Anim Behav Sci. Elsevier; 2008; 109: 320–328.
39. Jokinen O, Appleby D, Sandbacka-Saxén S, Appleby T, Valros A. Homing age influences the prevalence of aggressive and avoidance-related behaviour in adult dogs. Appl Anim Behav Sci. Elsevier; 2017; 195: 87–92.
40. Freedman DG, King JA, Elliot O. Critical period in the social development of dogs. Science. 1961; 133: 1016–7. https://doi.org/10.1126/science.133.3457.1016 PMID: 13701603
41. Fox MW, Stelzner D. The effects of early experience on the development of inter and intraspecies social relationships in the dog. Anim Behav. Elsevier; 1967; 15: 377–386.
42. Foyer P, Wilsson E, Wright D, Jensen P. Early experiences modulate stress coping in a population of German shepherd dogs. Appl Anim Behav Sci. 2013; 146: 79–87.

43. Harvey ND, Craigon PJ, Blythe SA, England GCW, Asher L. Social rearing environment influences dog behavioral development. J Vet Behav Clin Appl Res. Elsevier; 2016; 16: 13–21.

44. Foyer P, Bjällerhag N, Wilsson E, Jensen P. Behaviour and experiences of dogs during the first year of life predict the outcome in a later temperament test. Appl Anim Behav Sci. Elsevier; 2014; 155: 93–100.

45. Davies M. Geriatric screening in first opinion practice—results from 45 dogs. J Small Anim Pract. Wiley Online Library; 2012; 53: 507–513.

46. Dietz L, Arnold A-MK, Goerlich-Jansson VC, Vinke CM. The importance of early life experiences for the development of behavioural disorders in domestic dogs. Behaviour. Brill; 2018; 155: 83–114.

47. Riemer S. Effectiveness of treatments for firework fears in dogs. BioRxiv. 2019; 663294.