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Seizure-alerting behavior in dogs owned by people experiencing seizures☆

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ABSTRACT

Introduction: The unpredictability of epileptic seizures is considered an important threat to the quality of life of a person with epilepsy. Currently, however, there are no tools for seizure prediction that can be applied to the domestic setting. Although the information about seizure-alert dogs – dogs that display changes in behavior before a seizure that are interpreted by the owner as an alert – is mostly anecdotal; living with an alerting dog (AD) has been reported to improve quality of life of the owner by reducing the stress originating from the unpredictability of epileptic seizures and, sometimes, diminishing the seizure frequency.
Aim of the study: The aim of the study was to investigate, at an international level, the behaviors displayed by trained and untrained dogs that are able to anticipate seizures and to identify patient- and dog-related factors associated with the presence or absence of alerting behavior.
Methodology: An online questionnaire for dog owners with seizures was designed. Information about the participants (demographics, seizure type, presence of preictal symptoms) and their dogs (demographics, behavior around the time of seizures) was collected. In addition, two validated scales were included to measure the human–dog relationship (Monash Dog–Owner Relationship scale (MDORS)) and five different traits of the dogs' personality (Monash Canine Personality Questionnaire refined (MCPQ-R)).
Results: Two hundred and twenty-seven responses of people experiencing seizures were received from six participant countries: 132 from people with dogs that had started alerting spontaneously, 10 from owners of trained AD, and the rest from owners of dogs that did not display any alerting behavior (nonalerting dog (NAD)). Individuals' gender, age, or seizure type did not predict the presence of alerting behavior in their dogs. People who indicated that they experience preictal symptoms were more likely to have a spontaneously AD. The owner–dog bond was significantly higher with ADs compared with NADs, and ADs scored significantly higher than NADs in the personality traits "Amicability", "Motivation", and "Training focus".
Conclusion: This study collected a large group of dog owners with seizures reporting behavioral changes in their dogs before their seizures occurred. This was associated with the presence of preictal symptoms. The seizure-alerting behavior of the dog may have a positive influence on the bond between the owner and the dog.

1. Introduction

More than 30% of people with epilepsy never achieve complete seizure control [1]. The average seizure frequency for an adult with refractory epilepsy is 3 episodes per month with a duration of 1–2 min. However, the burden of epilepsy extends far beyond the occurrence of seizures, and it is well known that epilepsy has a negative impact on the individual's life independent from seizure frequency [2]. The unpredictability of seizures plays a major role in the lower quality of life

Abbreviations: SRD, seizure response dog; AD, alerting dog; NAD, nonalerting dog.

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This study was approved by the Ethical Committee of Ghent University Hospital, the Ethical Committee of the Fondazione IRCCS Policlinico San Matteo, and the Committee for the Protection of Humans Subjects of Dartmouth-Hitchcock Medical Center. After consulting with local authorities, no further approvals were needed for the other participating countries.

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perceived by patients with drug-resistant epilepsy [3–6]. This unpredictability limits the freedom to perform ordinary tasks (such as cooking or crossing the street), prevents them from performing various roles and jobs, and restricts overall mobility. Additionally, it gives patients a feeling of loss of control that influences their self-perception and may lead to anxiety and/or depression [2,7,8]. People with epilepsy and their caregivers rate the importance of being able to predict seizures as high or very high [9,10]. Being able to anticipate seizures is believed to have a positive effect on the life of people with epilepsy [11,12].

Currently available devices designed to detect seizures – such as accelerometers, other movement sensors, and multimodal detectors – can be used to alert a caregiver, but none provide advanced warning to the individual experiencing the seizure [3]. Devices that aim to predict seizures are usually based on the implantation of electroencephalogram (EEG) registration electrodes and the development of predictive algorithms [13]. However, it is still unclear if they are sufficiently accurate and practical for routine clinical application. In addition, EEG device implantation carries not insignificant risks, and even when deemed a reasonable option, some people may be reluctant to consider them [9].

During the past three decades, reports of dogs being of assistance to people with epilepsy have attracted considerable attention. Dogs can be trained to recognize and take action once a seizure has started. These dogs are known as seizure response dogs (SRDs), and they can be taught to notify a caregiver, to help the individual wake up after a seizure, and to bring useful items such as a telephone or medication. Some of these SRDs have been reported to spontaneously start anticipating their owner's seizures [14–16], displaying one or more typical behaviors that the owner learns to interpret as an alert. There is no evidence that the dog is trying to keep the owner safe, rather, it is regarded as an emotion that the dog is expressing in anticipation of the seizure. Interestingly, the spontaneous onset of behavior changes prior to a seizure has also been reported in pet dogs, although some authors have suggested that these originate from anticipatory fear of the owner's behavior during a seizure, whereas in trained SRDs, behavior is generally associated with the expectation of a reward [14,17,18].

In 1999, the first formally trained seizure-alert dogs emerged from the work of Support Dogs, a UK-based assistance dog training organization [15]. Support Dogs designed a training method based on the hypothesis that the dogs learn to recognize subtle changes in the behavior of their owner before the onset of a seizure. In addition, it was reported that the frequency of seizures decreased after the patients received their trained dogs, supporting the notion that reduced uncertainty and the perceived increase of control have a positive influence on seizure frequency [19,20].

Despite the substantial increase of seizure-alert dog training and public interest, scientific information is limited. In particular, no further attempts have been made to describe the population of trained and untrained dogs that seem to alert seizures. In addition, no systematic study into the reliability of the behavior nor into the potentially underlying mechanisms has been performed. Reports of dogs alerting to psychogenic nonepileptic seizures (PNES) have raised doubts about the ability of the dogs to anticipate true epileptic seizures [21,22]. Assessing to what extent dogs are consistent in anticipating seizures can help to decide if it is justified to rely on them for seizure anticipation. Knowing by which sensory system they detect changes in their owner before a seizure occurs could allow for a more targeted training process. Both of these issues are investigated in the currently ongoing EPIDOGS project.

In the present article, the results of the first work package of the EPIDOGS project are presented. The aim was threefold: (1) to build an international database of trained and untrained alerting dogs (ADs) and their owners, for use in the other EPIDOGS work packages, (2) to investigate the behaviors displayed by trained and untrained dogs that are able to anticipate seizures, and (3) to identify patient- and dog-related factors associated with the presence or absence of anticipatory behavior.

2. Materials and methods

2.1. Questionnaire design

We aimed to collect information from people with epilepsy living with a dog. However, the diagnosis of the epilepsy was self-reported by the participant. Because of the nature of the study (international online survey), it was not possible to have a confirmation of the epilepsy diagnosis by a treating neurologist. Therefore, we will use the term 'people with seizures' throughout this manuscript, instead of 'people with epilepsy'.

To collect information about people that experience seizures and about their dogs, three questionnaires were designed and administered using Survey Monkey: one for people with seizures older than 18, one for parents of children with seizures, and one for caregivers of people with seizures with impaired capacity. Inclusion criteria were the following: having been diagnosed with epilepsy (self-reported diagnosis) and currently living with a dog. Owning a dog displaying alerting behavior was not a requirement to participate, as we were also interested in examining differences between owners of dogs with and without alerting behavior.

The questionnaires were initially designed in English and then translated by native speakers into Dutch, French, Italian, Spanish, and German. A multilanguage website (https://epidogsproject.net) was set up, containing information about the study and links to access the questionnaires. The survey was first launched in Belgium and then in the following countries: Germany, Italy, Spain, the UK, and the US. Countries were selected on the basis of availability of the survey in the national language or, in case of multiple national languages, in at least one of them and on the possibility of obtaining an ethics committee approval.

The questionnaires were available online from September 2017 to July 2018. In order to reach participants, support organizations, social media groups, and medical centers were contacted and asked to display flyers both physically and via social media. Potential responders were not contacted directly but went to the website on their own initiative, after learning about the study. The participants gave their informed consent online and then completed the questionnaire.

The questionnaire consisted of 46 questions (7 multiple-choice questions, 11 open-ended questions, and 2 scales).

The first part included questions on basic demographic (age, gender, household composition, and country of residence) and clinical information, including the duration, frequency, and type of seizures experienced (according to the preservation or loss of consciousness/awareness during the seizure), presence of any preictal symptoms (e.g., symptoms preceding the onset of a seizure as defined by the participants, acknowledging that at least some of those symptoms could represent ictal activity not identified by the participant as such), interval between the preictal symptoms and the seizures, and presence of seizure triggers.

The second part of the questionnaire contained questions on the demographics of the dog and its behavior before, during, and after the seizures. Questions on the circumstances of the anticipatory behavior were also included (e.g., location, when did it start, how long before the seizure, etc.). Finally, the Monash Dog–Owner Relationship scale (MDORS) and Monash Canine Personality Questionnaire refined (MCPQ-R) were included. The MDORS is a validated scale divided in three subscales ("Owner–Dog Interaction", "Perceived Emotional Closeness", and "Perceived Costs"), developed to measure the bond between the owners and their dogs as perceived by the owner [23]. The MCPQ-R is a tool to evaluate dog personality differentiating between five different personality traits: Extraversion, Motivation, Training Focus, Amicability, and Neuroticism [24–26].

The MDORS was back-translated to 6 different languages. Since we were only interested in the bond established between the person with epilepsy and their dog as perceived by that person, this scale was only included in the questionnaire for adults. A previous translation [27] to

French and Dutch of the MCPQ-R was used. Translations for Spanish, German, and Italian were not available, and therefore, the MCPQ-R was not present in the questionnaires translated into those languages. If respondents had more than one dog, they could fill out the dog-related questions, the MDORS and MCPQ-R for each dog, with a maximum of four dogs.

2.2. Data analysis

Contradictory responses and responses from people that declared experiencing nonepileptic seizures were excluded.

2.2.1. Descriptive statistics

Responses were divided into those from owners of dogs that alert (AD) and those from owners of dogs that do not (nonalerting dogs (NADs)). The ADs were further categorized into trained and untrained, and the frequency of occurrence of each variable was calculated for each category. This exploratory descriptive analysis was performed using Microsoft Excel 2016.

2.2.2. Predictive and comparative analysis

A Kolmogorov–Smirnov test was used to assess distribution normality across the numerical part of the data set and to select appropriate statistical tests. Univariate binary logistic regression models were used to evaluate potential predictors of the presence or absence of anticipatory behavior in untrained dogs. Breed, reproductive status (females and males, neutered or not), and dog origin were included as dog-related potential predictors. Gender, age, seizure type, presence of preictal symptoms, and presence of triggers were included as human-related predictors. Prior to fitting the regression models, predictors were first tested for multicollinearity to make sure that none of the variables included in the regression were interassociated. All variables associated with a 0.1 significance level in the univariate regression were entered into a multivariate model, and the results were reported as odds ratios (O.D.).

The age of the participants was classified in 3 groups: younger than 12, between 12 and 18, and older than 18. The presence of seizure triggers was coded as a binomial variable: present or absent. The presence of preictal symptom was recoded to include the frequency with which the symptoms occurred. The categories were “No preictal symptoms”, “Rarely, sometimes or half of the time”, and “Most of the time and every time”. The variable “type of seizures” was also recoded to create mutually exclusive groups and to strengthen the model: Group I: “people with only seizures where they fall down unconscious”, Group II: “people with both seizures during which they fall down unconscious and seizures during which they do not fall down but are not able to respond”, and Group III: “people with only seizures during which they cannot respond to stimuli but they are not unconscious”. The remaining three people who exclusively experienced seizures during which they could respond to stimuli or seizures that were not noticed by other people were excluded from the model. The different dog breeds were split into 11 groups as identified by the Federation Cynologique Internationale (FCI) [28]. Since the number of “Spitzs and primitive types” was too low to include in the analysis as separate group, they were grouped with the “Pinscher and Schnauzer — Molossoid and Swiss Mountain and Cattledogs” groups.

For the cases where the patient experienced preictal symptoms and had a dog that showed anticipatory behavior, a Mantel–Haenszel test of trend was run to determine whether a linear association existed between the time that usually passed between the preictal symptom and what the respondent identified as the beginning of the seizure and the time that usually passed between an alert and the start of the seizure. Both variables were classified into five categories and scored from 1 (less than 1 min) to 5 (more than 1 h) in ascending order.

The MCPQ-R and MDORS scores were calculated following the procedures described by Ley et al. [25] and Dwyer et al. [23]. There were not enough trained dogs to compare the scores of trained and untrained dogs, but since we anticipated that the owners' perception about their dog's personality and the human–dog bonds could differ between trained and untrained dogs, the 11 trained dogs were excluded from further analysis. The scores of the MCPQ-R and MDORS refer therefore only to untrained dogs.

Regarding the MCPQ-R, the scores for the five traits of personalities of AD and NAD were compared using Wilcoxon signed rank tests. The Wilcoxon signed rank tests were also used to compare the MDORS scores of ADs and NADs. The total score was compared as well as the three different subscales: the “Dog–Owner Relationship”, the “Perceived Emotional Closeness”, and the “Perceived Costs”.

These statistical analyses were performed using SPSS Statistics 25 (IBM).

3. Results

A total of 238 complete responses to the dog owner questionnaire were received: 33 from Belgium, 10 from Germany, 73 from Italy, 70 from the UK, 27 from the US, and 14 from Spain. Eleven responses came from countries not included in the study and were dropped, leading to 227 respondents included in the analysis. Since respondents were given the chance of completing the dog-related questions for more than one dog, data from 247 dogs were collected and analyzed.

3.1. Information about the owners

Of the 227 respondents, 176 (74%) were adults with self-reported epilepsy, 27 (12%) were parents or guardians of children younger than 12, 15 (15%) were parents of children older than 12, and 9 (4%) were caregivers of people with impaired capacity. The average age of the people with seizures was 31 years (range 2–71), 72% of them identified themselves as females, 26% as males, and 2% as other. Ninety-two percent of the owners of AD and 89% of the owners of NAD live together in the same household with at least one adult.

Table 1 summarizes the seizure-related information collected from the participants according to the capacity of their dogs to alert.

Regarding the frequency of the seizures, most of the people that experience seizures with complete loss of consciousness, experienced them less than once a month (57%), 21% experienced them once a week, and only 5% experienced them daily. Seizures without unconsciousness but with impaired responsiveness occurred also less than once a month in 34% of the participants, 28% of them experienced them once per week, and 17% daily. Most of the participants indicated that they experience some type of preictal symptom (82%).

From the 227 responses received, 142 (63%) respondents declared to currently live with one or more ADs. The percentage of adults living with AD (62%) was similar to the percentage of children (64%).

3.2. Information about the dogs with anticipatory behavior

In total, 160 dogs (65%) were described to display alerting behavior. Ten dogs had been trained as an AD, and one had been trained as an SRD but did not display alerting behavior. Twenty-one respondents filled in the dog-related part of the questionnaire for more than one dog. Of those, two people have two trained ADs each, 7 respondents live with two untrained ADs, 10 respondents have at least one AD and one or more NADs, and 2 have more than one NAD and no AD.

3.2.1. Trained dogs

A summary of the information obtained regarding the location and time when the alerting behaviors usually happen can be found in Table 2. Thirty percent of ADs whose owners always experience preictal symptoms had displayed the behaviors when they were in a different room than the owner or while the owner was sleeping. This rose to more than 60% of ADs belonging to owners that never experience preictal symptoms.

Table 1
Summary of the seizure-related information received, expressed as the percentage (and total number) of participants from each group that indicated each one of the nonmutually exclusive options. AD: alerting dog; NAD: nonalerting dog; All: all participants.

	Living with AD	Living with NAD	All
Type of seizure according to the responsiveness status			
Person is completely unconscious and falls down	77% (109)	82% (109)	79% (179)
Person does not fall down but cannot respond normally to environment	72% (102)	79% (67)	74% (169)
Person is able to respond normally to environment	49% (70)	34% (29)	44% (99)
Seizures that no one else notices	66% (94)	53% (45)	61% (139)
Type of preictal symptom			
Funny feeling in the head	51% (73)	39% (33)	47% (106)
Funny feeling coming from the stomach	25% (36)	22% (19)	24% (55)
Tingling sensation	24% (34)	19% (16)	22% (50)
Visual symptoms	29% (41)	15% (13)	24% (54)
Auditory symptoms	11% (16)	13% (11)	12% (27)
Olfactory symptoms	13% (19)	8% (7)	11% (26)
Particular taste	15% (22)	9% (8)	13% (30)
Hunger, stomach sensation	18% (25)	19% (16)	18% (41)
Tiredness	35% (50)	24% (20)	31% (70)
Headache	31% (44)	27% (23)	30% (67)
Memory	35% (50)	33% (28)	34% (78)
Emotional symptoms	35% (50)	25% (21)	31% (71)
Sweating	22% (31)	20% (17)	21% (48)
Difficulty to speak	37% (53)	25% (21)	33% (74)
Problems of concentration	37% (52)	27% (23)	33% (75)
No symptoms	13% (18)	27% (23)	18% (41)
Others	8% (11)	2% (2)	6% (13)
Time between preictal symptom and seizures			
Less than 1 min	47% (54)	41% (24)	45% (78)
1–5 min	21% (24)	28% (16)	23% (40)
5–30 min	16% (18)	9% (5)	13% (23)
30–60 min	12% (14)	10% (6)	11% (20)
More than 1 h	5% (6)	12% (7)	7% (13)
Seizure triggers			
Lack of sleep	75% (106)	76% (65)	75% (171)
Stress	78% (111)	73% (62)	76% (173)
Alcohol	16% (23)	16% (14)	16% (37)
Menstruation	39% (39)	28% (18)	35% (57)
Flashing lights	20% (29)	27% (23)	23% (52)
Missing medication	57% (81)	52% (44)	55% (125)
Other	22% (31)	24% (20)	22% (51)
None	3% (4)	6% (5)	4% (9)

The most frequent alerting behaviors described (Fig. 1) were licking the owner – most frequently the hands – and staying close to the owner. Both of these behaviors were described for 70% of the trained dogs. Staring at the owner was also a frequent behavior with 60% of the trained dogs displaying it before a seizure. Other behaviors described were sitting next to the owner (30%) and touching the owner with a paw or the head (20%). One dog had additionally been trained to perform special behaviors like fetching the phone and attracting the caregiver's attention.

Table 2
Summary of the information received about the circumstances surrounding the alerting behaviors, expressed as the percentage (and total number) of participants from each group with trained or untrained dogs that indicated each one of the options.

	Trained	Untrained
Location of the alert		
At home in the same room as the participant	89% (8)	89% (8)
At home in different rooms	89% (8)	33% (49)
The owner was sleeping	78% (7)	32% (48)
In the street	100% (9)	22% (33)
In a shop/supermarket/another public building	100% (9)	7% (11)
In other people's house	89% (8)	13% (20)
In a place with many other people	89% (8)	17% (25)
In a place with few or no people	89% (8)	25% (37)
Other	0% (0)	8% (12)
Anticipation time		
0–1 min	0% (0)	27% (35)
1–10 min	0% (0)	36% (47)
10–30 min	37% (3)	14% (18)
30–60 min	63% (5)	11% (14)
More than 60 min	0% (0)	11% (15)

3.2.2. Untrained dogs

Regarding the location of the alerting behavior, most of the dogs had alerted when they were in the same room as the owner while alerting in the other situations described was less frequent (Table 2).

According to their owners, 36% of the untrained dogs started spontaneously anticipating the seizures from the first time they witnessed a seizure. Fourteen percent started during the first month and 14% between the first and the sixth month of living together. Another 36% started after one year or more.

The most frequent alerting behaviors according to respondents were staying close to the owners (62%) and licking them (48%) (Fig. 1). Licking the hands and the face are equally frequent and often happen together. Sitting next to the owner (41%), staring (40%), and vocalizing (32%) i.e., barking, growling, whining, etc. were other frequently reported behaviors.

Twenty-one percent of the dogs displayed “other behaviors” different to the ones offered in the questionnaire. Most people described attention-seeking behaviors like jumping, trying to get close, etc. Some people described the affective state of the dog using adjectives like “anxious”, “restless”, or “desperate” and mentioned behaviors that can be interpreted as related to fear or anxiety-related such as whining, trembling, “won't go near the person with epilepsy”, etc. One dog was

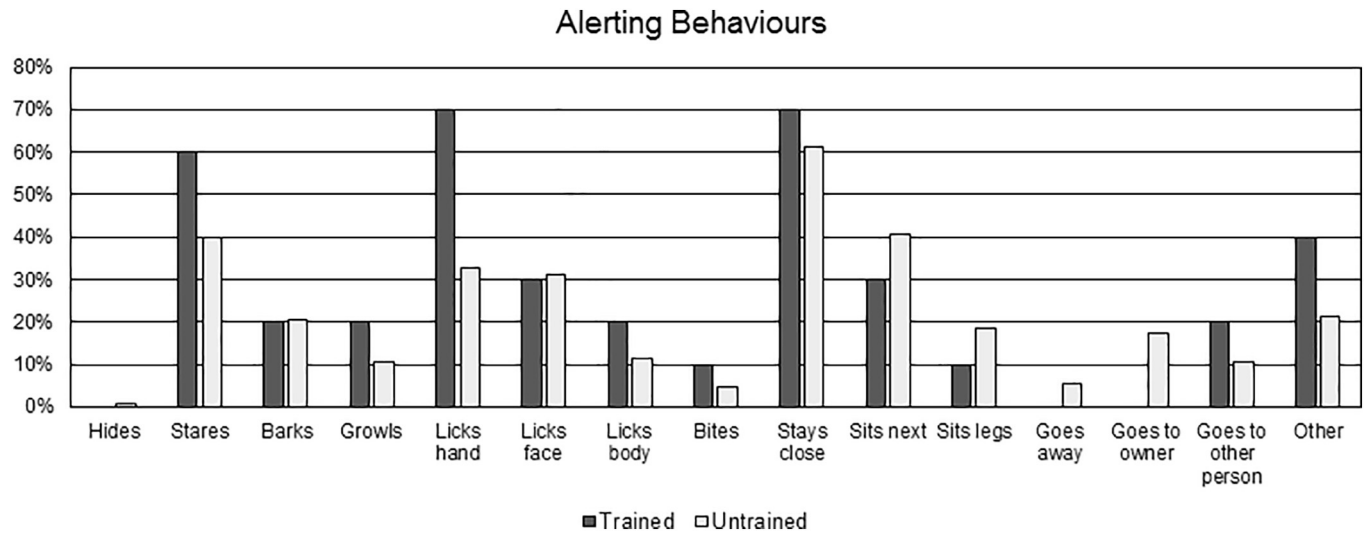

Fig. 1. Percentage of trained and untrained dogs that displayed particular alerting behaviors.

described to get "irritable with other dogs" before the seizures, and another would get aggressive with people trying to go near the owner.

3.2.3. Alerting vs nonalerting dogs

Fig. 2 shows a descriptive comparison of the behaviors during and after the seizures of ADs and NADs.

During the seizures, most ADs stay close to the owner (51%) or sit next to them (36%) while only 16% of NADs stay close and only 9% sit next to their owner. Licking the hands (23%) and face (26%) were also frequently described by owners of ADs. For NADs, the most frequently reported behavior was no reaction (31%), this was considerably higher than for ADs (3%). Sixteen percent of the owners of ADs indicated that

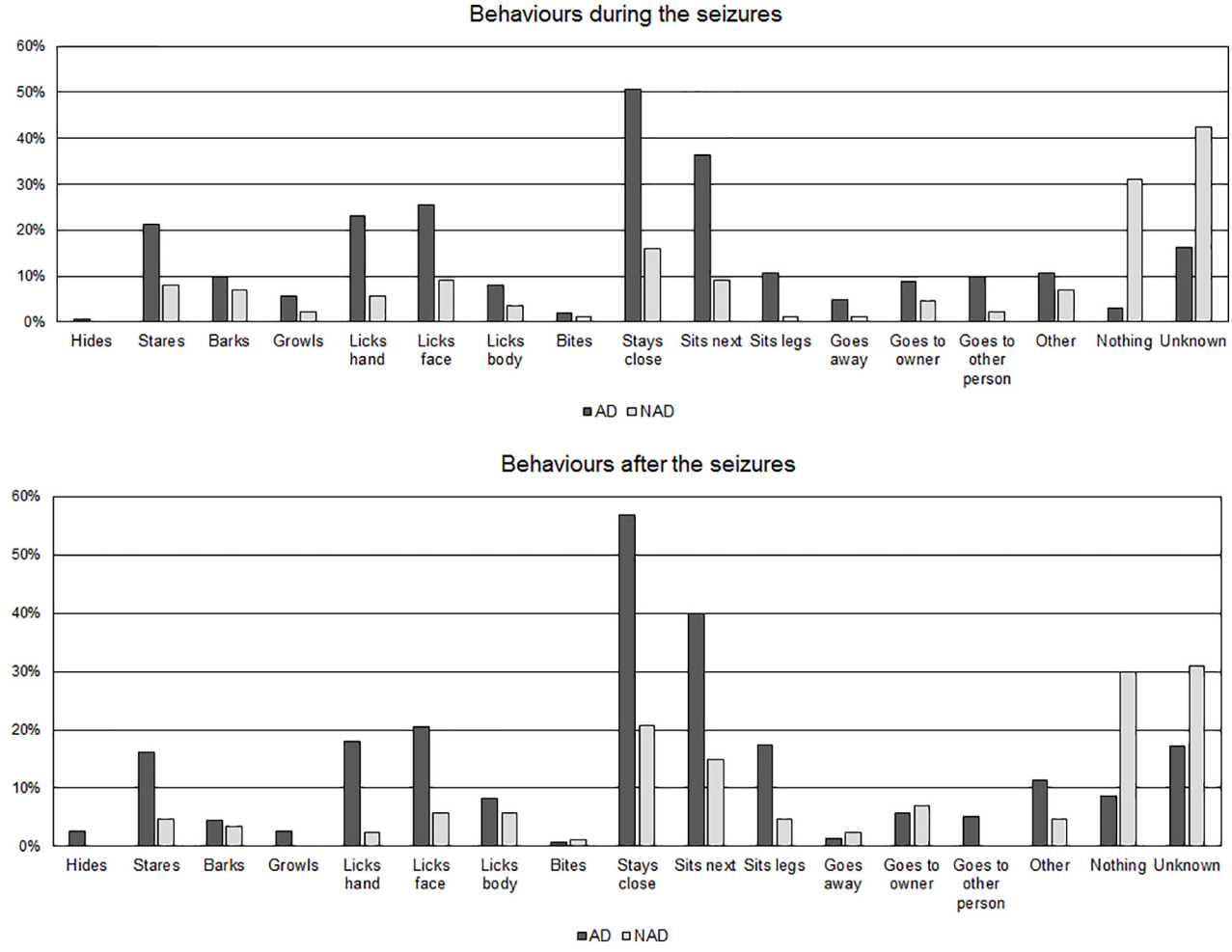

Fig. 2. Percentage of alerting dogs (AD) and nonalerting dogs (NADs) that display each behavior before, during, and after seizures.

they did not know the behavior of their dogs, compared with 43% of the owners of NADs.

Similarly, after seizures, respondents indicated that the most common behaviors displayed by ADs were staying close to the owners (57%) and/or sitting next to them (40%). The percentage of NADs that displayed those behaviors was considerably lower. Only 21% of NADs were reported as staying close to the owner and 36% sitting next to them.

3.3. Predictive statistics

Univariate predictors of the presence of alerting behavior in untrained dogs are presented in Table 3.

The presence of preictal symptoms, dog age when arriving home, and presence of triggers were included in a multivariable model (χ^2 (4) = 14.909; p = 0.005). Only the presence of preictal symptoms remained significant (p = 0.015). Preictal symptoms that occurred "most of the time" or "every time" were associated with the occurrence of anticipatory behavior (O.R.:3.004; p = 0.004).

3.4. Comparative statistics

The Mantel–Haenszel test of trend showed a strong, statistically significant linear association between time between preictal symptoms and seizures and times between alerting behaviors and seizures (χ^2 (16) = 21.36; p < 0.001; r = 0.445). Shorter times between preictal symptoms and seizures were associated with shorter times between alerting behaviors and seizures, and vice-versa.

3.5. Monash Canine Personality Questionnaire refined

Data for a total of 147 dogs were analyzed. Significant differences were found between NADs and spontaneous ADs in the traits of Motivation (Wilcoxon Signed Rank test: z = −2.436; n = 135; p = 0.015), Training Focus (Wilcoxon Signed Rank test: z = −2.078; n = 117; p = 0.032), and Amicability (Wilcoxon Signed Rank test: z = −2.147; n = 134; p = 0.032). The scores for those three traits were significantly higher in ADs than in NADs. There were no significant differences for Extraversion (p = 0.315) and Neuroticism (p = 0.074).

3.6. Monash Dog–Owner Relationship scales

The total Dog–Owner Relationship score, calculated using the three subscales [23], was significantly higher for ADs and their owners compared with NADs (Wilcoxon Signed Rank test: z = −1.992; n = 166; p = 0.046). Although there were no significant differences in the subscales "Emotional Closeness" (p = 0.131) or "Interaction" (p = 0,400), the score for the subscale "Costs" was significantly higher for ADs (Wilcoxon Signed Rank test: z = −3.088; n = 166; p = 0.002).

Table 3
Results of the univariate logistic regression for potential predictors of the presence of alerting behavior (*d.f.: degrees of freedom).

Variable	Wald	d.f.*	Sig.
Dog breed	6.907	7	0.439
Dog age when arrived	4.278	2	0.041
Dog reproductive status	1.274	3	0.735
Owner gender	0.023	1	0.911
Owner age	0.400	2	0.819
Preictal symptoms	9.501	2	0.009
Triggers	3.059	1	0.080
Type of seizure	1.797	2	0.409

4. Discussion

To our knowledge, this is the first study that includes a large, international population of people who report having epilepsy and are living with seizure ADs, thereby expanding and updating previous studies that focused on small, local populations [16,18]. It offers a description of periictal dog behaviors together with some clinical information that helps to build a context around the occurrence of these behaviors. In addition, the use of validated dog personality and human–dog bond scales provides, for the first time, a description of dog personality traits that seem to be strongly related to spontaneously ADs and suggests that the ability to display alerting behaviors may influence the human–dog bond as perceived by the owner. Finally, we compared the responses of owners of ADs and NADs to identify potential factors that may be associated with the presence of alerting behaviors.

4.1. Database of owners of ADs

The first aim of the study was to build an international database of people with seizures who own an AD, for future research in the EPIDOGS project. Most of the participants were adults with a self-reported diagnosis of epilepsy.

There was a notable difference in participation across countries. Most responses came from Italy and the UK while there was low participation in more populous countries like the USA and Germany. This could be due to a greater difficulty spreading the information about the questionnaire in those countries.

Although it was emphasized that having an AD was not necessary to participate, it is likely that people who thought their dogs had alerting abilities were more likely to take part, resulting in an overrepresentation of ADs. Nevertheless, the number of participants with NADs was large enough to make meaningful comparisons with ADs.

Considering that there do not seem to be epidemiological differences in the incidence of epilepsy between males and females [29], women seem to be overrepresented in this study, in line with existing evidence indicating that women are more likely to participate in online questionnaires than men [30,31].

In our study, the type and frequency of seizures showed a large variability, which is in line with population data on seizure epidemiology [32]. Most of the participants reported experiencing different types of seizures, with seizures causing complete loss of consciousness being particularly common, as it has also been previously reported in other population studies [32]. The majority of participants experienced seizures once a month or less. A large percentage of the participants, notably higher than previously reported in the literature [33,34], experience preictal symptoms before what they identify as the onset of the seizures.

As stated before, it was not possible to confirm that all participants had indeed been diagnosed with epilepsy. Consequently, our sample could contain participants without any seizures or with PNES, who knowingly or unknowingly provided incorrect information. The former is an issue for any study, like the current one, that uses snowballing and open access to a survey. To attempt to counter this, information on the questionnaire was spread exclusively through epilepsy support associations, epilepsy study groups, and medical centers. This will not, unfortunately, keep participants with PNES from participating as they are frequently referred to these centers [35]. Participants in our study with PNES may have provided answers that are determined by their psychological condition [35,36]. Based on the overrepresentation of women in our sample and the correlation cited in literature between the female gender and the higher likelihood to have PNES [36], we could assume to have several participants with PNES. However, the overrepresentation of women may also be due to the fact that they are more likely to fill out online surveys in general [30,31]. In addition, although Krauss et al. [37] suggested that patients with PNES may tend to seek the help of an assistance dog more often than other people,

most of the dogs in this study were pet dogs or trained dogs from organizations that require an epilepsy diagnosis before a patient can enter the training program. Nevertheless, for future research based on the currently established database, confirmation of the diagnosis will have to be sought from the treating neurologist.

4.2. Differences between ADs and NADs

4.2.1. Owner-related factors

The presence of preictal symptoms was a good predictor of alerting behavior of the dog. In addition, the interval between the onset of the symptoms and the seizures as identified by the participants was positively correlated with the time between the presentation of the alerting behavior and the seizures. One possible explanation for both findings is that the preictal symptoms, directly or indirectly, may trigger the alerting behavior of the dog. Most of these symptoms happen in the 30-minutes before the observable seizure, and it is likely that at least some of them represented a sensory ictal phenomenon (aura) possibly associated with subtle physiological or behavioral changes to which the dog may be reacting [21,34,38]. This change of behavior could act as a cue for the dog whether the owners are aware of it or not. Alternatively, it is possible that the owners, when experiencing preictal symptoms, tend to be more attentive to the dogs and/or tend to interpret the behavior of the dog as an alert. Finally, the finding that preictal symptoms are a predictor of dogs' alerting behavior could explain the overrepresentation in the questionnaire of participants that experience preictal symptoms as they more often have ADs and possibly were more likely to participate in the study.

Alerting behavior was unrelated to the gender and age of the owner as reported by Dalziel et al. [18]. On the other hand, Kirton et al. found that alerting behavior is more common in dogs living with children with epilepsy than in dogs living with adults [15].

Since it was anticipated that some of the participants may not know the precise medical terms for their specific seizure types, a classification according to awareness and responsiveness status [39] was also offered. We found that, using this classification, seizure type was not a good predictor of dogs' ability to anticipate seizures.

According to their owners, a high percentage of nontrained ADs started alerting from the first time they were exposed to a seizure. This finding was also reported in Kirton et al. [16] and could suggest that these dogs reacted to a change that they sensed in the owner before the onset of the first seizure. This would imply that they are not truly anticipating the seizure, as anticipatory behavior is considered to be the result of a learning process [40,41] where the dog learns, due to repeated exposure, that there is an association between a cue (behavioral, auditive, olfactory or other), that precedes the seizure and the seizure itself. However, we cannot exclude the possibility of recall bias, as some owners may not accurately remember the exact point in time when the dog started displaying the behaviors.

In this study, most people reported that their dog alerts when in the same room. However, similarly to the study by Dalziel et al. [18], dog owners who completed the present questionnaire often described being asleep or in different rooms when their dogs displayed alerting behaviors. In fact, one-third of the ADs belonging to participants that always experience preictal symptoms were reported to display alerting behaviors when the owner was sleeping or in a different room. This may further support the theory that some dogs react to an olfactory or auditory cue rather than only relying on the owner's behavioral changes.

4.2.2. Dog-related factors

As previously reported in SRDs that had started alerting [15], standing next to the owner was the most frequent behavior displayed, together with licking the owner's face or hands and staring. Behaviors potentially dangerous for the owner or suggestive of distress and/or fear in untrained dogs, previously described in the literature [17], were reported with a low frequency.

Regarding the behaviors displayed once the seizure had started, ADs that stayed initially next to the owner tended to remain in the same position during and after the seizure. Licking was also frequent in ADs once the seizure had started and until the owner had recovered. Most of NADs were reported not to change behavior during or after the seizure. Although fear-related behaviors have been previously described in spontaneously ADs [17], the occurrence of those behaviors was low in the questionnaire. It is possible, however, that owners perceiving the behavior of their dog as negative may have been less likely to participate in the questionnaire.

Neither the reproductive state, breed, nor origin of the dog were predictors of the development of alerting behaviors. This finding has also been reported in the previous studies [16,18].

There were differences between ADs and NADs in some of the personality traits explored by the MCPQ-R. Alerting dogs scored significantly higher in Motivation, Amicability, and Training Focus. In contrast, neurotic animals were less likely to alert, although the difference was not statistically significant. This conflicts with the common belief that dogs defined as nervous or anxious start alerting because they tend to be more attentive to their environment. Some training organizations approached for this study declared that they look for certain personality traits in potential trainee dogs (personal communication), some of which have been associated with the personality traits described by the MCPQ-R, such as self-confidence (low Neuroticism), problem-solving abilities and play-drive (Training Focus) etc. [42,43]. However, because of the small number of trained ADs in this study, it was not possible to perform a comparison between the trained and untrained groups.

The human–dog bond differed substantially in the "Perceived Costs" subscale, with ADs scoring significantly higher than NADs. These costs not only refer to the economic costs of dog ownership but also to other negative aspects such as disruption of normal routines or increased responsibility [23]. Owners of ADs gave less importance to these negative effects of owning a dog compared with owners of NADs. However, there were no significant differences in the subscales "Interaction" or "Emotional Closeness". The Total Bond Score, calculated using the three subscales, was also significantly higher for AD owners suggesting that the perceived cost–benefit or value of dog ownership is influenced by the owner's perception that the animal alerts them.

4.3. Differences between trained and untrained dogs

The number of owners of trained ADs was insufficient for formal comparisons with spontaneously ADs, but signals suggesting differences between trained and untrained dogs emerged. The main difference was in anticipation time, with the interval between the onset of alerting behavior and the onset of an observable seizure being more consistent (always between 10 and 60 min) in trained dogs. These results are similar to the ones presented by Brown and Strong of dogs trained by Support Dogs [20] who reported that their ADs displayed the behaviors between 15 and 45 min before the seizure. In contrast, untrained dogs varied between less than 1 min and 48 h in advance. This could reflect the fact that trained dogs have all been trained to react to the same cue, selected by the trainers – i.e., changes in behavior in Support Dogs' case – that appears during that particular time window. Conversely, untrained dogs could be reacting to different cues that they have come to identify as a sign of an oncoming seizure. The main anticipatory behaviors were similar in both groups, although untrained dogs displayed a wider range of behaviors. Only one participant owned an SRD, but it had not developed any alerting behavior.

5. Conclusion

The main objective of this study was to study the population of ADs as perceived by their owners and to find potential differences

with NADs. Most of the participants identified behavioral changes in their dogs before their perceived onset of seizures, and this was associated with the presence of preictal symptoms. The presence of seizure-alerting behavior may have a positive influence on the bond between the owner and the dog. The results are largely consistent with existing reports but include a wider international population.

Further research is needed to investigate the relationship between preictal symptoms experienced by people with a confirmed epilepsy diagnosis and the spontaneous occurrence of alerting behaviors in their dogs, as well as the mechanisms that trigger the alerting behaviors in both patients with epilepsy and PNES.

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Declarations of interest

None.

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