Can Dogs Predict Earthquakes? A Possible Auditory Answer

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The suggestion that animals can sense earthquakes before they occur was first recorded in Greece in 373 BC, when dogs howled and many rats, weasels, snakes, and centipedes moved to safety several days before a destructive earthquake. In China and Japan animals are considered to be an integral part of their national earthquake warning systems. One early indication of their usefulness occurred in 1975, when officials in the Chinese city of Haicheng were alarmed by odd and anxious behaviors of dogs and other animals. These observations led them to order 90,000 residents to evacuate the city. Only a few hours later a 7.3 magnitude earthquake destroyed nearly 90 percent of the city's buildings. Since then a number of studies have suggested that animals can anticipate seismic events(1,2).

A serendipitous event provided an opportunity to explore the ability of dogs to predict earthquakes. Behavioral data on variations in canine moods was being collected from 200 dogs. Twice a week owners were sent an e-mail and asked to rate activity level and signs of anxiety in their dog over the previous day using a nine point scale(3). In general there was little day to day variability in group averages, however one particular day (02/27/2001) showed a sharp increase in activity (+1.85, $t[192]=19.02$, $p<0.001$) and anxiety (+1.38, $t[192]=9.47$, $p<0.001$). Of the 193 dogs reported that day, 47% (91) were more than two standard deviations above their usual baseline for activity and 49% (95) for anxiety. By chance, I had captured data on dog behaviors on the day before a 6.8 earthquake shook the Pacific Northwest. With a focus not far from Vancouver, Canada, it shook the city with enough intensity to cause damage to some structures.

It has been suggested that one possible explanation for animals "predicting" earthquakes is that their superior auditory sensitivity allows them to hear seismic activities that precede earthquakes(1,2). In the sample 14 dogs were reported as having hearing impairments. Consistent with possible auditory cuing, only one showed any significant increase in anxiety or activity, and it was living with a normal hearing dog (not in the sample).

To further explore the possibility of an auditory cue the sample was divided into dogs with lopped ears whose ear flaps attenuate sounds somewhat (N=122) compared to dogs with pricked ears (N=71). Dogs with pricked ears showed greater mean increases in activity (+2.97 versus +1.19, $t[191]=11.35$, $p<0.001$) and anxiety (+2.47 versus +0.75, $t[191]=6.20$, $p<0.001$).

Sound attenuation by an ear flap is greater for high frequencies since low frequencies bend around objects. Thus a beagle's ear flap interposed between a 90 dB, 1000 Hz tone source attenuated the sound reaching a sensor 2 cm behind it by 6.2 dB, compared to 31.1 dB for a 14000 Hz tone. Ear flap differences could mean that higher frequency sounds are critical. To test this, dogs were rank ordered according to head size (using average inter-aural distance per breed) and divided into thirds. Smaller head sizes are associated with better sensitivities for high frequency sounds(4,5). Consistent with the importance of high frequencies, the 65 dogs with smallest head sizes showed greater increases than those with the largest head sizes for pre-earthquake activity level (+2.88 versus +1.16, $t[128]=8.26$, $p<0.001$) and anxiety (+2.22 versus +0.96, $t[128]=3.72$, $p<0.001$).

Taken together these results are suggestive. It appears that there is an increase in observable activity and anxiety in dogs in the 24 hours preceding an earthquake. Observations that dogs with poor hearing are not affected, and dogs with lopped ears are less affected, hint that animals are responding to an auditory cue. The fact dogs with smaller head size are more responsive is consistent with a presumption that higher frequency sounds serve as the signal predicting an impending earthquake, perhaps from rocks scraping or breaking underground,.

Obviously, analysis based upon a single event, even though the sample size is reasonably large, can not be considered a definitive proof. In addition statistical sensitivity was augmented by the fact that baselines were extremely stable because they were computed from 54 data points per dog. However the results are internally consistent and suggest that canine sensitivity to higher frequencies allows them to serve as bioindicators of future seismic events.

References and Notes

1. M. Ikeya, *Earthquakes and animals: from folk legends to science.* (World Scientific Publishing Co., Singapore, 2004).
2. T. Miller, *Earthquake Prediction Handbook.* (Info-Pub, San Bernadino, CA, 1996).
3. Materials and methods are available as supporting material on Science Online.
4. B. Masterton, H. Heffner, R. Ravizza, *J.Acous. Soc. Am.*, **45**, 966 (1969).
5. R.R. Fay, *Hearing in Vertebrates: a Psychophysics Databook.* (Hill-Fay Associates, Winnetka IL, 1988).

Footnote

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Supporting Material Follows Below

Change in Dogs' Activity and Anxiety Levels on the Day Before an Earthquake (27 Feb. 2001)

Baseline data --based on 54 data points per dog (Sept 5/00-April 5/01—two observations per week, randomly distributed over Monday to Friday—break in data acquisition sequence over Xmas holidays)

Anxiety Change

Baseline	1.98 (0.11)		
Pre-Quake	3.37 (2.03)		
Difference	1.38	t(192)=9.47	p>0.001

Activity Change

Baseline	3.05 (0.13)		
Pre-Quake	5.35 (1.35)		
Difference	1.85	t(192)=19.02	p>0.001

Number increasing more than 2 Standard Deviations from baseline

Anxiety	95 (49%)
Activity	91 (47%)

Ear shape effects

Anxiety Change

Pricked	2.47 (1.72)	
Lop Eared	0.75 (1.93)	
Difference	t(191)=6.20	p>0.001

Activity Change

Pricked	2.97 (0.95)	
Lop eared	1.19 (1.10)	
Difference	t(191)=11.35	p>0.001

Head size effects

(Ranked based on breed sizes—select top and bottom third)

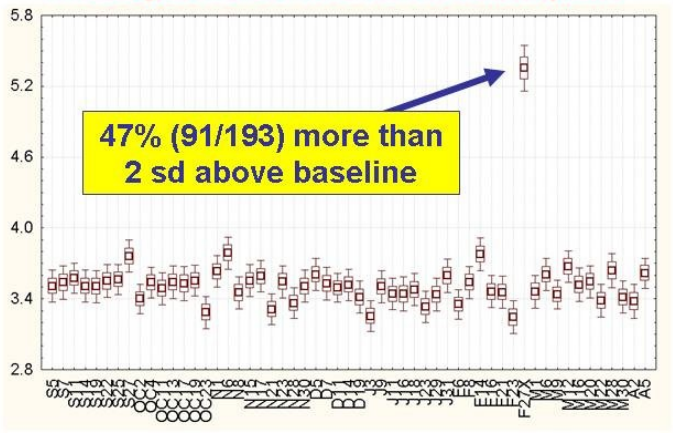
Anxiety Change

Smallest	2.22 (1.86)	
Largest	0.96 (2.01)	
Difference	t(128)=3.72	p>0.001

Activity Change

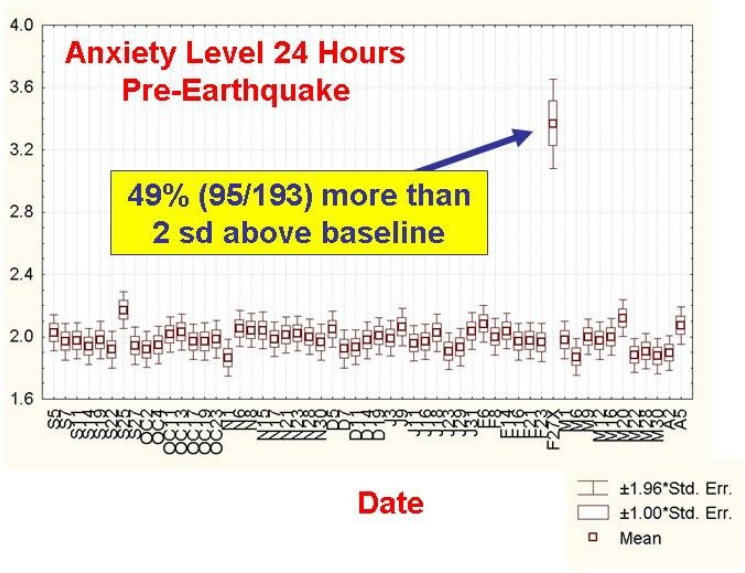
Smallest	2.88 (1.12)	
Largest	1.16 (1.26)	
Difference	t(128)=8.26	p>0.001

Activity Level 24 Hours Pre-Earthquake



Date

±1.96*Std. Err.
±1.00*Std. Err.
Mean


Anxiety Level 24 Hours
Pre-Earthquake
49% (95/193) more than
2 sd above baseline
4.0
3.6
3.2
2.8
2.4
2.0
1.6
Date
±1.96*Std. Err.
±1.00*Std. Err.
Mean

Materials and Methods

Baseline data for 193 dogs' activity and anxiety levels was gathered between September 5, 2000 and April 5, 2001. There were 54 data points per dog for each scale, computed from two observations per week, randomly distributed over Monday to Friday with at least one day between observations. There was a break in data acquisition sequence over the Christmas holidays. The critical observation gathered on the day before the earthquake (February, 27, 2001) was not included in the baseline computation.

Main body of data acquisition e-mail sent twice each week.

Dog Mood Survey

Thank you for your continuing assistance with this project. Simply hit the e-mail "Reply" button on your mail program, then fill in the two numbers and send this message back to us. You are providing information about (Dog's name inserted here).

Please rate your dog's general activity level over the past 24 hours (date of previous day inserted here) using the following scales. If for some reason you did not receive or open this message on (date of mailing inserted here) or if you did not have an opportunity to observe your dog on (date of previous day inserted here) don't fill in the data, just return the message with the answers blank.

Activity Level

1 = Much less active than usual
2 = A little bit less active than usual
3 = Usual or average level of activity
4 = Marginally more active than usual
5 = Somewhat more active than usual
6 = Clearly more active than usual
7 = Much more active than usual
8 = Very much more active than usual
9 = Annoyingly or worrisomely more active than usual

My dog's activity level yesterday was _____ (enter number)

Dog's Mood

1 = Very placid and calm
2 = Usual or average level of calmness
3 = Marginally less calm than usual
4 = Seemed a bit worried, cautious or vigilant once or twice
5 = Seemed a bit worried, cautious or vigilant for brief periods, several times during the day
6 = Seemed to be somewhat anxious about something for a prolonged period

7 = Definitely worried, anxious or fearful about something (panting or pacing)
8 = Very worried, anxious or fearful about something (hiding or cringing)
9 = Extremely worried, anxious or fearful (trembling, drooling, or trying to escape the house or yard)

My dog's mood yesterday was _____ (enter number)