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Brief Communication

Mouse Circadian Rhythm Before the Kobe Earthquake in 1995

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Mouse circadian diagrams recorded at Osaka University showed unusual mouse behavior before the Kobe earthquake on January 17th, 1995. The locomotive activities on January 16th showed drastic increases, several times above the standard deviation, during both sleep and active periods, indicating that mice perceived of some preseismic signals. Bioelectromagnetics 24:289–291, 2003.

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Retrospective reports by lay people of unusual animal behavior before the 1995 Kobe earthquake, which had a magnitude (M) of 7.3, reinforced old legends about earthquake prediction [Rikitake, 1974; Wadatsumi, 1995]. Alleged causes of unusual animal behavior were charged aerosol [Tributch, 1982], magnetic field [Kirschvink, 2000], and electromagnetic (EM) pulses [Ikeya, 1999]. The latter work recently studied as seismic EM signals (SEMS), occurring at the time of microfracture of rocks ahead of a large earthquake. However, most scientists are skeptical of these phenomena and consider such reports as simply post hoc recollections under the psychological conditions of a natural disaster. Although the credibility of stories by ordinary citizens is always controversial and "afterthoughts" must inevitably be involved, old legends and reports by citizens about earthquake precursors should not be dismissed out of hand, given the tremendous casualties caused by large earthquakes.

So far, most statements on unusual animal behavior were subjective reports by lay people and lacked objective data observed by scientists. However, mouse circadian (daily) rhythms recorded at Institute for Protein Research, Osaka University, 50 km away from the epicenter of the Kobe earthquake, present scientific evidence of unusual animal behavior among genetically controlled mice prior to the major earthquake.

The circadian rhythms of four mice, each in one cage, were under investigation. Locomotive mouse movements in nine sectors on the floor were monitored in January 1995 with infrared light, and their cumulative activities were recorded automatically every 30 min to obtain a standard circadian diagram. One cage was broken by the earthquake, but three remained. Disturbed rhythm was noticed after the earthquake. The frequency of the total daily activity in January was analyzed statistically.

Figure 1(a) shows the mouse circadian diagram with before and during the earthquake occurrence. A mouse sleeps in light and move actively in dark periods. The rhythmic activities up to January 15th changed after January 16th. Activities were high on the night of the 16th when unusual phenomena were observed, as can be seen by comparing actual activity in Figure 1(b), the average rhythm from January 1st to January 15th (open circles) during light (sleep) and dark (active) periods. The same tendencies were observed in the

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circadian diagrams of other three mice, as discussed later in the statistical analyses.

The frequency of total daily activities is given in Figure 1(c) with the average of daily data for the half-month prior to January 15th and the standard deviations σ for both periods. The activities on 16th for the sleep period, active period, and 24-h activities were deviated by $+10.8\,\sigma$, $+4.3\,\sigma$, and $+3.8\,\sigma$, respectively. There are difficulties in dealing with a rare occurrence event like a big earthquake. The data of extreme variates, called "outliers," on a single day of January 16th were further analyzed with statistics of a single observation [Sokal et al., 1997]. The normality test indicated that the probabilities of such unusual behavior are statistically 0.80 and 0.89 for sleep and active periods, even using the small sample size from the limited period in January. One of the authors (Dr. Katsuya Nagai), noted that except before the Kobe earthquake, unusually disturbed circadian rhythms without any apparent reason have not been observed in 15 years of research activities, which usually involve keeping ten mice at Institute for Protein Research. That means the unusual behavior was

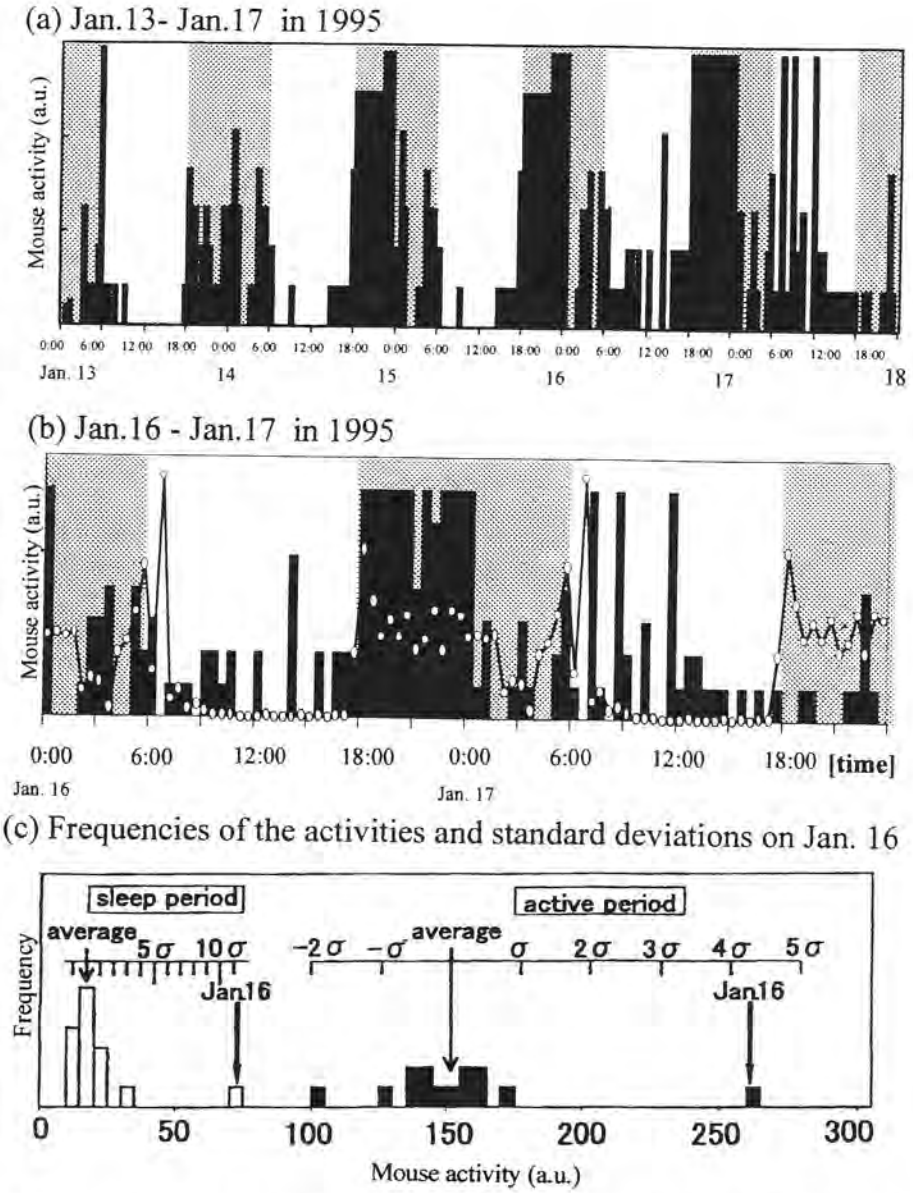

Fig. 1. Mouse circadian rhythm before the Kobe earthquake at 5:47, January 17th, 1995: (**a**) the rhythmicity and its disturbance after January 16th. (**b**) comparison of activities on 16th with the mean rhythmic activities (open circles); the dark active period is shaded. **c**: Frequencies of the total daily activities in the light and dark periods with their averages, standard deviations and activities on 16th.

observed with a probability of one per 55,000 days on the day before the earthquake. Apparently, mice perceived certain preseismic signals a day before the Kobe earthquake.

There were reports by lay people of on radio and TV noises and malfunctioning of home electric appliances, such as spontaneous switching and buzzing [Ikeya et al., 1998]. Unusual noises in EM pulses at different frequencies before the Kobe earthquakes were also reported by an astronomical observatory [Maeda and Tokimasa, 1996] and by telecommunication engineers [Hayakawa et al., 1996]. Reported SEMS at ULF observed before the Loma Prieta earthquake was 60 pnT/Hz$^{1/2}$ (about 1 MW/m^2·Hz or 20 mV/mHz$^{1/2}$) [Frazer-Smith et al., 1990]. The magnetic field is only one millionth of the Earth's magnetic field, and so animals detecting it through ferromagnetic biominerals in their body [Kirschvink, 2000] would not panic, as reported by citizen. What animal sense, is involved, whether magnetic field, electric field, or EM field is still controversial. However, we consider that animals are affected by EM field. It would be probably the electric field of SEMS, which is larger than 20 V/m (1 W/m^2) according to data from the Loma Prieta earthquake that startled animals.

Aquatic animals with electrosensory organs, like catfish and shark, can detect 10^{-5} V/m, corresponding to a peak energy of 10^{-12} W/m^2 of EM pulses; catfish are known to move violently before earthquakes in Japanese legends. An experiment with electric field effects at the Kobe-Oji Zoo surprised sea lions at 0.5 V/m [Ikeya et al., 1997]. Land animals may sense the electric field EM pulses. In fact our experiment of EM exposure to mice indicated that they were startled by EM pulses of about 0.3 V/m and also by the compression of granitic rock which generated EM pulses. Work on the electric field effects on animal behavior will be published separately.

Although mechanisms of generation of EM pulses during crack formation have not yet been clarified, mechanical compression of rocks was shown to generate EM pulses and unusual animal behavior in laboratory experiments [Ikeya et al., 2000]. Preseismic EM pulses in the geosphere should be studied scientifically for short term earthquake forecasting, although the separation of seismic EM pulses from those of lightning and artificial noises poses technical difficulties. Furthermore, deterministic prediction of earthquakes might still be difficult, even though we could roughly tell the fracture of rocks in experiments using a constant rate of compression.

Thus, scientific observation of unusual animal behavior, like our automatic monitoring of circadian rhythms using genetically controlled mice, should be done simultaneously with observation of EM pulses and EM waves at different frequencies. These may provide a more useful form of information than the direct EM observation. In any event, unusual animal behavior may still be an alarm for citizens in their daily lives to prepare themselves for disaster, as our ancestors did in the legends of earthquake prone areas.

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