were housed as follows: chamber 1, contingent males; chamber 2, noncontingent males; chamber 3, noncontingent females; and chamber 4, contingent females.

The animals remained undisturbed until they were 60 to 62 days old; daily filling of pellet dispensers and water reservoirs was done briefly in the dark with a minimum of disturbance. At this point, each animal was tested in the open field for 2 minutes per day for four consecutive days. The open field, similar to that described by Broadhurst (5), was a walled circular arena 83 cm in diameter; walls and floor were painted white, and black concentric circles and sections of radii divided the floor into segments used to score activity. Subjects were removed from their chambers for testing in a different random order daily and were returned to the chambers immediately after testing. On day 86, all subjects were weighed..

The defecation scores for the 4 days of testing are shown in Table 1. Animals reared in contingent chambers defecated significantly less than those reared in noncontingent chambers ($F_{1,12} = 6.34$; $P < .05$). As the mean values and the lack of a significant treatment by sex interaction indicate, the differences were consistent for both sexes.

The mean activity scores for the two groups are shown in Fig. 1. The mean activity of the contingent animals was higher than that of the noncontingent animals on days 2 and 3. An analysis of variance of activity scores indicated that, for the two groups, the difference in these patterns of activity scores across the 4 days of testing approached significance (groups-by-days interaction: $F_{1,12} = 2.56$; $.10 > P > .05$). Weights of the groups were compared by *t*-test to determine whether the defecation difference was due to some nutritional difference between the two groups. The weights of the two groups were not significantly different ($t = 1.56$, d.f. = 14, $P > .10$).

The data indicate that control of aspects of their environment affected the adult behavior of the rats. The results do not indicate whether the contingent environment reduced emotionality or whether the noncontingent environment increased it in relation to rats reared in normal laboratory conditions; however, the amount of control experienced by the noncontingent subjects appears to be comparable to that experienced in a normal laboratory setting. In addition, the effects obtained are not clearly attributable to environmental conditions in early life, since the animals were housed in the environments from birth to early adulthood. However, in a subsequent study of rats that were not placed in the chambers until they were weaned (21 days), there were no differences in open-field behavior, a result suggesting that the effect may, in fact, be developmental. Further investigation is necessary before any substantive conclusions can be reached on this point.

Table 1. Number of defecations in 4 days of open-field testing; S.E., standard error.

Group	Defecation score (mean ± S.E.)
Contingent males	8.5 ± 1.12
Noncontingent males	11.0 ± 2.10
Contingent females	4.75 ± 2.52
Noncontingent females	12.0 ± 1.62

It appears that animals with a substantial amount of control over certain environmental consequences display a behavior pattern in the open field which can be characterized as less "emotional" than that of animals not in direct control of these consequences. This reduction in emotionality is similar to the effects of other treatments—including handling, shock, cooling, and social contact—none of which were systematically different in this experiment. Consequently we appear to have identified control over environment as another variable that affects emotionality. Further studies of the effects of environmental contingencies during development on learning ability and reactions to stress should indicate the extent of the effect produced by differences in the amount of early environmental control, and should give further evidence concerning the similarity of the effects of this manipulation to the effects of perceptions about locus of control.

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10. Six-watt, 28-volt bulbs were used. One response on the appropriate lever turned the lights on, the next response turned them off.
11. The four chambers in which subjects were reared, each 24 by 45 by 60 cm, had wooden walls and ceilings and wire mesh doors and floors. Each chamber contained a food dish, a water dish, three response levers, and a light mounted above the chamber. The levers were 5 by 8 cm and were mounted approximately 1 cm above the floor. The use of large levers eliminated the need to shape or formally train the lever-pressing response. All levers and dishes were mounted on one wall of each chamber. Scientific Prototype (model L700) feeders served as the food delivery system and Skinner electric valves (model C2DA1081) delivered water.
12. Rats were obtained from Blue-Spruce Farms, Altamont, New York.

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Geyser Eruptions and the 18.6-Year Tidal Component

Rinehart (*1*) stated that "over 40 years of records from Yellowstone National Park, Wyoming, show that the 18.6-year tidal component strongly regulates the frequencies of eruption of Grand and Steamboat geysers." However, an important event in the recent history of the park overshadows the tidal effect and invalidates his claim for its control on the geyser eruptions. This event was the earthquake of 17 August 1959 (magnitude 7.1 on the Richter scale) whose epicenter was located within 47 km of Grand and Steamboat geysers (*2*). A number of aftershocks were observed in the months following the main event, some with magnitudes between 5 and 6.5 on the Richter scale. Because geysers and hot springs depend on heated groundwater and are mainly located in alluvium, glacial till, or highly altered rhyolite, they were immediately affected and their activity either increased, decreased, or became erratic. On 18 August 1959 the activity of Grand Geyser ceased completely, and it remained dormant for several months (*2*). These events stand out clearly in figure 1 of Rinehart's report (*1*). To conclude that tidal forces are directly responsible for this behavior of Grand Geyser is therefore very risky.

Because of the earthquake, the

eruption records from 1959 until at least 1965 (when Grand Geyser regained its former activity) are useless for correlation with tidal forces. It may be coincidental, but it is interesting that Grand's activity from 1955 to 1959 and from 1965 to the present was essentially constant. With the removal of the eruption data from 1959 forward, the correlation coefficient appears to be well below the reported .5.

For Steamboat Geyser, Rinehart reports a correlation coecient of $-.4$ (or $-.9$ with a 1-year phase shift) based on 6 years of data, or about one-third of a tidal cycle. His data start in 1963, 3.5 years after the major earthquake. Steamboat Geyser has been observed, however, since 1878 (*3*). It has been known as a nearly perpetual spouter with a height of 1.5 to 6 m and a period of about 5 minutes; only five major eruptions were recorded before 1912. Major eruptions started again in 1961, either as a result of subterranean changes initiated by the 1959 earthquake, or because of the characteristically changing nature of the thermal activity of Norris Geyser Basin (*3*). The amount of external and internal erosion caused by these major eruptions indicates that similar activity could not have taken place unobserved between 1912 and 1961. Thus, Steamboat's major eruptive phase should be considered an extraordinary event that partially coincided with a portion of the cyclic tidal force curve. To count this as evidence for control by the 18.6-year tidal component is questionable.

The behavior of Steamboat Geyser during this major eruptive phase has been typical of many geysers in Norris Basin; internal erosion and redeposition of material in their plumbing is so severe that their eruptions cease within a few seasons. Norris Basin has a history of new thermal features breaking out or old ones being rejuvenated every few years (*3*). The idea that this behavior is cyclic and might be correlated with the tidal component is interesting; however, I do not believe the data needed for this correlation have been collected in sufficient detail for a sufficient period of time. In fact, data to show a meaningful correlation of the activity of any geyser or thermal area with the 18.6-year tidal component may be hard to come by for four reasons. (i) The area is frequently jolted by earthquakes (*2*). (ii) Thermal features often change progressively as silica deposits grow in and around them. (iii) Groundwater flowing into the basin may exhibit long-period fluctuations. (iv) Environmental changes due to tourist activity and park development may disturb the thermal activity (*4*). Any of these effects could be more significant in a particular case than the long-term tidal force component. To demonstrate this tidal effect convincingly would require a good correlation over at least two cycles for several geysers. The most likely candidates for this will be geysers that now show correlations with the short-term components of tidal force. The problems Rinehart encountered in attempting to make a correlation from the available data point up the need for more complete, continuous recording of the activity of thermal features and of events that might have a direct effect on thermal activity.

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31 August 1972

Geer's cautionary remarks emphasize the strong influence that tectonic stresses associated with earthquake activity can have on geyser activity. I have already shown (*1, 2*) that these stresses have appreciable effects on two Yellowstone geysers, Old Faithful and Riverside. At Riverside the tectonic stresses accumulating for a few weeks preceding several local earthquakes nearly mask the effects of the tidal forces [figure 3 in (*1*)]. However, the data for Grand and Steamboat, and for many other geysers, show that such effects are generally short-lived (a year or so at most), and there appear to be no long-term effects.

It is, of course, difficult to separate explicitly the various parameters affecting geyser activity. The Hebgen Lake earthquake could indeed have caused the sudden drop in Grand's activity in 1959, but it does not explain the good correlation with tidal forces that persists over the years. The sudden drop in the activity of Steamboat, around 1966, seems too far removed in time from any effects of the Hebgen Lake earthquake. Steamboat's spectacular eruptions occur when the tidal forces are lower. Although relatively low heat flow might be expected at low tide, it is possible that an instability has a better chance of developing then, since at high tide the higher heat flow keeps this geyser in a constant state of agitation.

Since writing the report under discussion, I have acquired more data on Steamboat and analyzed data for a number of other geysers (*3*); these data seem to corroborate the relation between the 18.6-year earth tide and geyser activity. Beehive and Giant at Yellowstone for the past 100 years and Old Faithful at Calistoga, California, for the past 10 years (the period for which records are available) seem especially sensitive to long-term tidal forces.

I strongly support Geer's suggestion that thermal activity in Yellowstone National Park be more extensively monitored.

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