Fig. 3. Two-sided rotating brass mirror placed in front of cathode ray tube.

Fig. 4. Stereoscopic pair produced by photographing a single display. See text for viewing instructions.

image are fused and the combination appears as a three-dimensional display.

The technique has been used to generate three-dimensional graphical displays, and, in particular, vector electrocardiograms, and it has obvious applications to research on visual perception.

NOTE

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What does the ultrasonic activity recording device measure?¹

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Rats were observed while their behavior was being monitored by an ultrasonic activity recording device. It was found that the device yielded more counts when Ss were being more active. But very active behavior is relatively rare, so that most of the counts over a period of time are likely to result from the more frequent but less active kinds of behavior, such as grooming.

Peacock and Hodge (1962) have described a device for recording bodily movement that consists of a very high-frequency (40 kHz) sound source and receiver. The basic principle is that as long as S does not move, the receiver will pick up a reflected signal of constant intensity, but if S moves around in the sound field, then the field will be distorted and the intensity of sound reflected back to the receiver will vary accordingly. The received signal is detected, i.e., rectified and integrated, and put through a pulse amplifier, so that the rate at which output pulses are generated is proportional to the rate of modulation of the reflected sound signal. This modulation rate is presumed to be proportional to the rate of movement of S within the sound field.

Although different kinds of movements by different kinds of Ss are potentially measurable with Peacock and Hodge's device, it has been used primarily to measure the general activity of the rat. The present paper is concerned just with this application. We pose the question: what do the rat's different activities contribute to its general activity score as measured by the ultrasonic device? What is the rat likely to be doing when the device reports that it is being active?

METHOD

A single test cage was used. It was a standard 7 x 7 x 10 in. hardware cloth living cage, with the front wall replaced by Plexiglas to facilitate observation of S. The cage was suspended in a 2-ft cubicle that was lined with acoustic tile on all sides except the front. The ultrasonic transducers were located about 4 in. apart, to one side of the cage, and approximately 7 in. from the nearest wall of the cage. The cubicle was located in a sound-attenuating isolation room and S could be observed through a one-way window without being disturbed. Light in the isolation room was on (approximately 10 ft-c) for 9 h a day, and during the remaining 15 h of darkness, illumination sufficient to see S was provided by a single 24-W red light bulb.

The Ss were 60-day-old male rats of Wistar descent. After they were adapted to the ultrasonic test situation for 24 h, the observations were begun. Food was never available in the situation, but a drinking tube was provided in the ceiling of the test cage. Observation sessions were approximately 5 min long. During these intervals S's behavior was scored on a 4-point scale. The E pressed one of four buttons on a keyboard for as long as S continued in a given class of behavior. The button gated the output of the ultrasonic receiver to one of four banks of counters, and gated the output from a clock to four other sets of counters. Thus, the raw data for each session consisted of the accumulated time S was engaged in each of the kinds of behavior, and the number of ultrasonic counts recorded while S was engaged in each of the kinds of behavior. The four classes of behavior were: Still (asleep, or lying motionless), Sniffing (head and vibrissa movement without body movement), Grooming (scratching, fur licking, and face washing, together with the brief pauses that typically interrupt such behavior), and Activity (locomotion, rearing on the hind legs, exploration, and drinking).

The ultrasonic device was a solid-state version of the one described by Peacock and Hodge (1962), which is commercially available from Alton Electronic Company, Gainesville, Florida. Its output is in the form of a voltage that shifts abruptly between 0 and 36 V at a rate that is supposed to be proportional to S's activity. The "sensitivity" control is, in effect, a gain control that alters the proportionality constant in some undisclosed manner. The output of the Alton device is compatible with BRS Electronics units, and can be used as the direct drive for a Digits flip-flop.

Two series of observations were made. The first series was made with a sensitivity setting of "7," a value that had been found in our situation to be near cutoff (see below) for an S that was Still. The first series of observations involved recording S's behavior for about 5 min every 30 min for a 24-h period. The purpose of sampling the daily activity cycle was to insure that there was no bias in the energy or vigor (i.e., the ultrasonic score) of any of the classes of behavior as a function of the time of day. Having found no such bias, we made a second series of observations, mostly in the early dark, with different settings of the sensitivity control, i.e., 6, 7, and 8. This series of observations involved three different Ss, each of which was about 24 h food deprived at the time of observation.

RESULTS

There were no systematic individual differences, nor time-of-day differences in the rate of ultrasonic counting for a given class of behavior. Hence the data were pooled across Ss and across times of day; they represent approximately 5 h of observation at Sensitivity 7, and 1 h each at Sensitivities 6 and 8. The mean number of counts per second were calculated for each class of behavior, and are shown in Fig. 1.

It is apparent that the number of counts per second generated by a particular kind of behavior increases with increased sensitivity settings. Moreover, the shape of the sensitivity function is very nearly linear, at least over the range of sensitivities for which the Action device is likely to be used in studies of the rat's general activity. Thus, the effect of increasing sensitivity is generally to add a constant to the mean count rate generated by a given kind of behavior. It is also apparent that when S increases its activity level there is a corresponding increase in the rate at which counts are generated, and that these increases, too, are additive rather than multiplicative. Thus, increasing either the sensitivity or the activity level of S produces a constant increment in the rate at which the ultrasonic device produces counts. This additive principle appears to hold down to a cutoff point, i.e., the point at which the sensitivity function

Fig. 1. The response of the ultrasonic activity device as a function of its sensitivity setting and the ongoing behavior of the rat.

would go to zero, but then there is a gradual trailing off so that counts are still made, but at a reduced rate. This was the case for sleeping. We observed that even when S was motionless and asleep there were still some ultrasonic counts being generated. Adding the few counts that occurred when S moved in its sleep, and the few counts produced when S was evidently awake and lying still, we found count rates of .52/sec at a setting of 7, and .24 at a setting of 6.

DISCUSSION

Two questions can be asked at this point. One is whether the number of ultrasonic counts increases with increased activity level. The answer here is evidently yes, and to this extent the ultrasonic device measures what it is supposed to measure in the general activity of the rat. But there is a second question to which the answer is neither so obvious nor so encouraging. What is the rat likely to be doing when the ultrasonic device indicates it is being active? An answer here requires an estimate of how much of the time the rat is engaged in the different kinds of behavior. Rather than use the present data, which were based upon the observation of a single S over just 24 h, we may use the more substantial estimates reported by Bolles (1967, p. 287): Still 66%, Sniff 6%, Groom 19%, and Active 7%. Multiplying these figures by the activity-count values shown in Fig. 1 yields the estimated contributions to the total number of counts made by the different classes of behavior. The proportions of the total are shown in Fig. 2.

Although the rat produces more counts per second being active than grooming, it spends so much more time grooming that the total daily counts contributed by grooming is far in excess of the number contributed by being active. This peculiar state of affairs is most obvious at sensitivities of 8 and higher, where the rat accumulates most of its ultrasonic counts while sleeping. It is

Fig. 2. The percentage of total daily counts to be expected from the ultrasonic device from the different behaviors of the rat as a function of the sensitivity setting.

only below sensitivities of approximately 5, where most of rat's behaviors are below cutoff, that the most active forms of behavior can possibly make the dominant contribution to the total daily counts. At this point the ultrasonic device is responding to only a fraction of the rat's total behavior, and is probably counting essentially the same forms of behavior that the common photocell device would be counting. The chief difference would be that whereas the photocell detects a sample of instances of locomotion and rearing, the ultrasonic device would presumably detect all instances of these behaviors. Thus, whereas the photocell may generate a few hundred counts a day, the ultrasonic device would be generating up to 50,000 counts a day.

We do not know what sensitivities other Es have used with the ultrasonic device (the difficulty of specifying the sensitivity setting of it is one serious limitation), but Peacock and Hodge (1962) mention obtaining 100,000 counts a day, which amounts to about 1.2 counts per second. We may assume, then, that their sensitivity corresponded to a setting of approximately 6 in our situation, and that they were, therefore, counting mainly instances of grooming.

It could be argued that it does not matter too much what kinds of behavior the ultrasonic counts are based upon. As long as an experimental manipulation leads to more vigorous forms of behavior, an ultrasonic activity recorder will show an increase in the total number of counts. This is true enough as far as it goes, but it is now known that certain common types of experimental manipulations lead not so much to overall increases in activity but rather to changes in the pattern of activity (Bolles, 1965). Thus, for one example, water deprivation reduces grooming and increases wakeful lying still. Water deprivation might be expected, therefore, to decrease total daily counts at all but the highest sensitivity settings. As another example, we may suppose that eating, which occupies approximately 9% of the ad lib rat's time, will generate counts at a rate somewhere between sniffing and grooming, and that after food deprivation, such behavior must be replaced by a lot of quite vigorous behavior, or there would again be a net loss of counts at most sensitivity settings. Such anomalies can be expected, of course, with any activity measuring device that does not tell us precisely what S is doing when it is being "active."

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Liquid level detector with automatic refill and depletion indicator¹

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An electromechanical device is described that provides the means for measuring the amount of water consumption from a storage device and for an automatic refill system. The instrument uses three sensing electrodes located in the storage bottle to drive a solid-state Darlington circuit, which, in conjunction with two liquid solenoid valves, controls the operation of the system.

In many behavioral experiments it is often necessary to measure the exact amount of water intake of animals over many

hours, days, or even months of experimentation. Most manual methods of liquid refilling are inexact when the measurement of precise volumes are needed and require regular attention to insure that the water supply is never exhausted.

The solid-state detector described herein provides the E with a very accurate and precise technique for controlling automatically the refill of the water supply reservoir and recording the exact amount of water consumed over long time periods.

In operation, water is supplied from a graduated container by gravity feed. When the water level falls to a lower limit an open circuit occurs between two of the electrodes and a fill solenoid is activated. The outlet of the container is closed during the fill