The Longitudinal Study of Activity and Avoidance over the Life Span of the Laboratory Rat[1]

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Abstract

The time involved in determining changes in behavior throughout the lifetime of the laboratory rat has resulted in a dearth of information concerning lifespan developmental changes in the behavior of this widely used experimental animal. The present report provides the preliminary results of a longitudinal study of changes in activity and avoidance learning over the laboratory rat's normal life span. Activity in the open field and performance on a shuttle-box discriminated avoidance task was measured in a group of 96 random bred Wistar rats at 60, 160, 220, 500, 560, and 660 days of age. The subjects were divided with respect to sex and order of testing while time and cause of deaths were recorded. The measures obtained from each animal included (1) escape and avoidance latencies (2) number of avoidance responses, and (3) activity in the open field. The changes in all measures were relatively small. Activity scores for all subjects combined showed an initial decrease in activity to age 220 followed by a subsequent increase at 500 and a decline at 560 days of age. The mean avoidance performance for all Ss increased throughout the six tested ages although the mean latencies declined steadily. Significant interactions also occurred with respect to sex and order of testing.

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The study of age changes in behavior has generally been handicapped by the fact that longitudinal studies of human subjects outlive the investigator if carried over the organisms entire life span. Cross-sectional designs have consequently been used widely to estimate age changes, but comparisons of findings from cross-sectional and longitudinal study show major discrepancies. The reasons for these discrepancies have been discussed in detail on previous occasions (Schaie, 1965, 1967a; Baltes, 1968).

Explication of the relationships between the cross-sectional and longitudinal methods has suggested the possibility of estimating age changes by using various designs involving the short-term longitudinal study of cross-sectional samples covering the entire age range of the organisms to be investigated (Schaie, 1966, 1967b). Partial applications of these strategies to human Ss have recently been conducted (Riegel, _et al_., 1967; Schaie & Strother, 1968a; 1968b), but a complete test of the basic general developmental model can only be conducted upon an organism having a significantly shorter life-span than its investigator.

Preliminary to conducting such complex programmatic study, we have felt that we must gain more experience in the life span study of the organism of choice. We have therefore established a colony of laboratory rats which we have now maintained for the past 28 months. The present paper will report our experiences in maintaining this colony throughout the major portion of the animals' life span as well as the age changes in performance on two standard laboratory tasks found suitable for monitoring the animals' behavior in a long term study.

The operations selected for this study involved the testing of our Ss on a discriminated avoidance learning task and in open field exploration at selected intervals from 60 to 660 days of age. The particular tasks were selected in part for the practical consideration that the time required to test animals must not be extensive, since otherwise it becomes impossible to test a reasonably large number of animals at any specified age.

Although the literature contains a number of studies investigating the relationships between age and avoidance learning the restricted age range investigated has often been a serious limitation to an adequate interpretation of the relationship. Briefly, Kirby (1963) found no differences in learning and extinction of conditioned avoidance responses among rats trained at 25, 50, and 100 days of age. Similar results have been obtained by Campbell and Campbell (1962) and, except for 25-day-old animals being inferior to 100-day-old S, by Thompson et al. (1965). Denenberg and Kline (1958) studying a more extended age range found 60-day-old animals somewhat superior (but not significantly so) during acquisition of the avoidance response followed by 225-day-old Ss and then 30-day-old animal. During extinction the 30, 60, and 225-day groups differed significantly with the 30-day-group extinguishing most rapidly and the 225-day group showing the greatest resistance to extinction. In two studies extending the age range of the animals investigated Doty (1966; 1966b) investigated animals from 25 to 730 days of age. She found no difference in trials to criterions as a function of age in a simple discriminated avoidance task but did find that Ss in the extreme age group required significantly more trials to reach criterion on a delayed avoidance problem and on problems with the trials relatively massed.

Age-related changes in open-field exploration have been reported by Broadhurst (1958) who found that locomotion increased significantly from 53 to 100-day-old animals but not from 111 to 238-day-old Ss and by Furchtgott et al., who report a decrease in open-field locomotion from 30- to 163-day-old S's, but not from 163- to 373-day-old animals. The present investigation, although it is in no way an attempt to replicate the studies by Furchtgott and Broadhurst, provides data over a greatly extended age range.

METHOD

Subjects

The subjects were fifty-one male and fourty-five female albino rats selected randomly from the young, born within a three day period, of twenty pregnant females obtained from a commercial supplier.

Procedure

The discriminated avoidance learning trials were administered in four identical Miller-Mower type shuttleboxes 30 in. long, 10 1/2 in. wide, and 6 in. high. A light source, producing a 10 ft. candle change in illuminations at the grid, projected through two flashed opal panels of glass in the ceiling at the ends of the boxes served at CS. The UCS was a scrambled shock source adjusted to produce a dependable running response. The intertrial interval, measured from the beginning of one trial to the beginning of the next trial averaged 1 minute. An avoidance response was recorded if the S crossed the mid-point of the shuttlebox within a 5 second CS-UCS interval and response latencies were recorded.

The open field is essentially a box or compartment 45" x 45" x 20" high. The floor of the compartment is covered with 9" x 9" blocks of black asphalt tile which divides the floor into twenty-five 9" x 9" squares. The walls are painted a neutral gray and the compartment is uniformly illuminated from above. Exploratory activity of the S was determined by recording the total number of blocks the animal traversed in a three minute test period.

At all ages tested each subject was given ten discriminated avoidance trials and one three minute exposure to the open field. The Ss were tested at 60,-160,-220,-500,-560 and 660 days of age. One fourth each of the 96 subjects were bred following the 60 day of age testing and following the 160 day-of-age testing in order to provide younger Ss of the same strain for additional studies planned with the aged population. The bred-unbred variable was entered into the analysis of the last four test ages. The order of testing was varied to control for the effect of shock on activity. One half of each group of Ss received the avoidance trials followed by the activity measure and the remaining Ss were tested in the reverse order. In addition, the order of testing was arranged so that subjects were tested in the same order at 60 and 660 days of age. The complete design outlined in Table 1 provides an analysis of sex, order of testing and breeding.

RESULTS

Survival. Maintaining a colony of animals over their life span seems to be accompanied by a comedy of errors in successive installments. We had intended to have our sample equally balanced by sexed, but upon the first test discovered that we had mis-sexed three animals. Our early attrition was also not primarily related to natural causes. As has been previously reported by others (Jones & Kimmeldorf, 1963) at 500 days our sample was virtually intact. Of the ten animals lost at that point two died from respiratory infections, four were "assassinated," i.e., killed when a graduate assistant erroneously selected animals out of the developmental colony upon being instructed to randomly thin out cages in the rat holding room, and four did not survive a bout of "labor trouble" which resulted in freezing temperatures in one of our rooms. From that point on, however, attrition speeded up sharply with 65% of the colony surviving at 560 days, and 57% surviving at our last test point of 660 days. At the time this paper is written the colony is 800 days old and we still have 38 animals or approximately 40% of the original number.

As will be seen from an inspection of Tables 1, 2 and 3 that there is approximately equal survival by sex but there are some interesting trends for selective survival as a possible function of breeding and test order. Thus it was found that survival rate is slightly better for the bred animals with a clearly significant interaction between sex and breeding; i.e., significantly more female bred animals survive at 660 days than is true for the non-bred animals. A trend was also noted for higher rate of survival among those animals who were observed in our open field situation before being tested in the avoidance situation. The reason for this difference seems obscure to us at this point.

Avoidance behavior. Results of the tests of avoidance behavior in the shuttle box apparatus are presented in Tables 4 through 6. Table 4 gives means by sex and for the total group at the six test ages. For the group as a whole there was a significant increment in number of avoidances until 220 days with a subsequent asymptote. There appears, however, a significant interaction with the animals sex. The male animals show a sharp increase from 60 to 160 days but then reach a plateau with a further sharp rise at 560 days. The female animals on the other hand show a continuous increase in avoidance behavior to 220 days with a subsequent drop at 500 days, return to peak at 560 days and renewed decrement at 660 days.

The second measure of avoidance behavior was the animals' response latency. For the group as a whole latencies declined steadily with age. Here also some sex differences occurred with the males showing a virtual plateau from 220 to 560 days and the females reaching an apparent asymptote after a significant drop in latencies from 160 to 220 days.

Tables 5 and 6 examine the animals response as a function of breeding and test order. There seems to be a trend for bred males to show systematically more frequent avoidance behavior than is true for the non-bred group. No such trend appeared for the female animals. There was tendency, however, for the bred females to show higher latencies until 500 days of age. Order of testing, as should be expected, yielded significantly higher avoidances and lower latencies for the groups of animals who were given the avoidance test after having been exposed to the open field apparatus. This difference however, disappeared with age for the females at 500 days and with the males at 660 days.

Activity. The activity measure for the total group showed an initial decrease from 60 to 220 days and a subsequent rise above the original level at 500 days. A subsequent decline at 560 days was followed by rise of activity to the previous peak at 660 days. The increment at the oldest age was, however, much more substantial for the male than for the female animals. A general tendency appeared for the bred females to be more active at all ages. A sex difference in the opposite direction was shown by the males at all ages except 560 days. The effect of test order on activity was significant at the first testing with animals being measured before shock showing higher activity level. On subsequent test occasion the effect of test-order varied in an apparently random pattern.

DISCUSSION

The results of our study suggest that it is important to consider the effects of environmental control in the laboratory as well as common treatment factors such as the decision to breed animals or the order of test procedures upon survival of a colony over its life span. It appears that these variables are of minor importance during the first 500 days of the rat's life, and our study confirms earlier reports on this span as being characteristic for the survival of one's entire samples. Beyond this stage, and for those interested in studying the behavior of very old rats, it seems important to plan carefully to reduce the effects of attrition due to environmental manipulation adversely related to survival in the laboratory rat.

The present study further suggests that avoidance measures obtained with the shuttle-box and open field measures of activity are convenient and practical procedures where relatively large numbers of animals are to be tested at several specified points in time. Our findings with respect to age changes in activity and avoidance behavior agree with previous findings in the literature although the interactions with breeding are intriguing and require further exploration.

Our analyses have been conducted on the assumption of random attrition from natural causes over all groups. Consequently we have compared the means of the survivors with the means of the total groups at earlier ages. In view of the fact that we seem to find significant interactions with conditions of breeding and test-order, closer attention needs be given to a separate comparison of survivors and non-survivors as well as an examination of age gradients for individual animals. Further comparisons of this type are planned and will be repeated separately.

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