Open-field activity of retinal regenerate C3H mice: Further evidence of some visual capacities

Z. MICHAEL NAGY

Bowling Green State University, Bowling Green, Ohio 43403

Six groups of rd C3H mice were tested in the open field under various illumination conditions for 4 consecutive days. Two groups were tested under either a high or low level of illumination on each day, while the other groups were exposed to an illumination change following the first of 2 test minutes. Two groups received a 1-sec change to the other level and then a return to the original illumination level. The two remaining groups received the entire second minute of testing at the other illumination level. The finding that activity changed in a predictable direction as a function of the illumination change suggests visual functioning of some degree in this strain.

Anatomical research has demonstrated that mice with the inherited abnormality of retinal degeneration (rd) undergo spontaneous degeneration of the retina during the second week of life and appear to lose their visual capacities quickly. Tansley (1954) and Sidman & Green (1965) have reported that the retina appears to develop normally in several rd mouse strains from birth until about 2 weeks of age, at which time there begins a rapid spontaneous degeneration of the central retina. By 3 weeks of age, the entire photoreceptor layer is virtually destroyed, although bipolar and ganglion cells may yet remain intact (Sidman & Green, 1965). Behavioral evidence has shown that mice with normal retinas perform better than rd mice in a number of tasks, including black-white perception (Wimer & Weller, 1965), maze learning (Lindzey & Winston, 1962; McClearn, 1958), and depth perception on the visual cliff (Fox, 1965; Frank & Kenton, 1966). The general assumption has been that the rd strains performed more poorly than the normal strains due to their blindness.

Several other studies with the rd C3H mouse, however, provide evidence that some visual capacities remain after the main degeneration period. Ross, Nagy, Kessler, & Scott (1966) have reported that 30-day-old C3H/HeJ rd mice were more active in an open field when tested under low illumination of the field than when tested under high illumination, a finding also reported for some mouse strains with normal retinas (DeFries, Hegmann, & Weir, 1966), and assumed to be visually mediated. A similar finding was reported for 50-day-old C3H mice (Nagy & Forrest, 1970), and Nagy & Misanin (1970) have further extended this finding, demonstrating that C3H mice retain the capacity to detect large brightness differences in

the open field until at least 100 days of age, although having lost the ability to discriminate differences in depth on the visual cliff task by 50 days of age.

The purpose of the present experiment was to examine further the ability of rd C3H mice to respond to brightness differences in the open field. In this study, illumination changes were produced within the open field testing trials to determine if these changes would produce corresponding within-trial activity changes.

SUBJECTS

The Ss were 120 male rd C3H mice born and reared in 11 x 6½ x 5 in. polyethylene cages with wire grid tops, wood-chip shavings on the floor, and ad lib access to food and water. The Ss were weaned at 30 days of age and placed with 3-4 males of the same age, but of different litters, into similar cages until testing at 50 days of age. All Ss were maintained in the laboratory colony at 74° ± 2°F, 50% ± 2% humidity, and on a 12-h light-dark cycle.

APPARATUS

The apparatus consisted of a 36 x 36 x 12 in. square field of unpainted Masonite. The floor was divided by black lines into 36 6-in. squares. Illumination was provided by a 150-W incandescent bulb placed 30 in. above the center of the field, with a silver-foil reflector placed directly above the light to provide even distribution of light to all parts of the field. The illumination level was controlled by a Type 116B Powerstat variable transformer, providing a high-illumination condition of 100 fc (140 V) and a low level of 1 fc (40 v). An air conditioner provided a steady background noise level of 63 dB and maintained the temperature of the open field at 72° ± 1°F.

PROCEDURE

Prior to testing, all Ss were earpunched for identification. At 50

days of age, each S was assigned to one of six experimental conditions, according to a modified split-litter design, with 20 Ss in each group. Each open-field trial was of 2 min duration and consisted of one of the following illumination conditions: (1) constant high-level illumination of 100 fc for 2 min (H-H); (2) constant low-level illumination of 1 fc for 2 min (L-L); (3) first minute at 100 fc, second minute at 1 fc (H-L); (4) first minute at 1 fc, second minute at 100 fc (L-H); (5) first minute at 100 fc, 1 sec at 1 fc, second minute at 100 fc (H-L-H); (6) first minute at 1 fc, 1 sec at 100 fc, second minute at 1 fc (L-H-L). Thus, two groups (H-H, L-L) received a constant level of illumination for 2 min; two groups (H-L, L-H) received one level for the first minute, a change in illumination to the other level, and the remainder of the trial at the second level; two groups (H-L-H, L-H-L) were exposed to one level for the first minute, a 1-sec change to the other level, and the second minute at the original level.

The number of squares entered was recorded separately for the first and second minutes of the trials, and one trial was administered each day for 4 consecutive days. The field was cleaned between each S tested.

RESULTS AND DISCUSSION

The activity scores during the first and second minute in the open field were summed over the 4 test days for each S. These data were first analyzed by a two-way analysis of variance with one repeated measure. The factors were illumination condition and minutes in the field. Neither the main factor for illumination condition ($F = 0.55$; $df = 5, 114$) nor minutes in the field ($F = 0.60$; $df = 1, 114$) was significant. However, the Illumination by Minutes interaction was reliable ($F = 3.88$; $df = 5, 114$; $p < .005$), indicating that activity changed

Fig. 1. Mean change in activity from first to second minute of test as a function of illumination condition.

Table 1
Mean Activity Differences Between
Illumination Conditions During
Second Minute of Test

	H-L-H	L-L	H-H	L-H-L	L-H
H-L	7.0	17.9†	19.3†	21.5†	33.2†
H-L-H		10.9	12.3	14.5*	26.2†
L-L			1.4	3.6	15.3*
H-H				2.2	13.9*
L-H-L					11.8

* $p < 0.1$, † $p < .05$

differentially from the first to second minute as a function of the illumination condition. Individual comparisons between the first and second minute of testing showed no reliable changes for H-H, L-L, and L-H-L (all $F_s < 1.00$; $df = 5,114$), reliable increases in activity during the second minute for H-L-H and H-L ($F_s = 3.67$ and 9.64 ; $df = 5,114$; $ps < .005$), and a reliable decrease in activity for the L-H group ($F = 6.39$; $df = 5,114$; $p < .0005$).

Since the main interest in this study was to determine how the different illumination conditions affected activity following a change or no change in illumination and also because it was not feasible to equate the different groups for activity prior to testing, the relative extent and direction of activity change was examined for each group. Each S was assigned a difference score obtained by subtracting its total 4-day first-minute score from its 4-day second-minute score. Figure 1 illustrates the amount and direction of activity change for all groups from the first to second minute of testing. It is clear that when illumination is constant throughout the trial (L-L and H-H), within-trial activity remains fairly constant, despite the fact that overall activity was greater under low ($\bar{X} = 102.4$) than under high ($\bar{X} = 84.9$) illumination. A change in illumination as short as 1-sec duration causes within-trial activity to change in a

predictable direction, although neither change is reliably different from groups under constant illumination. Finally, within-trial activity reliably increases or decreases when the illumination is decreased or increased, respectively, during the second half of the trial (H-L and L-H). The difference scores were analyzed by a simple one-way analysis of variance which indicated a reliable difference between illumination conditions ($F = 3.87$; $df = 5,114$; $p < .005$). The mean differences between groups of within-trial activity changes and the significance levels of individual comparisons are presented in Table 1.

These findings are further supported when the number of Ss showing activity changes in a particular direction during the second minute are examined. Table 2 presents the number of Ss in each illumination group which increased, decreased, or showed no change in activity from the first to the second minute of testing. It is apparent from this table that the activity changes which were reliable were not due to only several animals in the group making rather large changes in activity during the second minute, but rather to substantial numbers of animals changing in the predicted directions.

In conclusion, these results demonstrate that rd C3H mice not only respond to brightness differences in the open field, but are capable of perceiving and reacting to within-trial illumination changes fairly quickly. These results provide further support to the contention that either some brightness perception is possible without the photoreceptor layer or that the degenerative process is not as complete in this C3H strain as it is in the P/Jax (Tansley, 1954) or C3H/HeJ (Sidman & Green, 1965) strains.

REFERENCES

DeFRIES, J. C., HEGMANN, J. P., & WEIR, M. W. Open-field behavior in mice: Evidence for a major gene effect

Table 2
Number of Ss in Each Illumination Group
Which Increased, Decreased, or Showed No
Change in Activity During Second
Minute of Test

	Increase	Decrease	No Change
H-H	10	10	0
L-L	9	10	1
L-H-L	10	10	0
H-L-H	13	6	1
H-L	15	5	0
L-H	3	17	0

- mediated by the visual system. *Science*, 1966, 154, 1577-1579.
- FOX, M. W. The visual cliff test for the study of visual depth perception in the mouse. *Animal Behaviour*, 1965, 13, 232-233.
- FRANK, R., & KENTON, J. Visual cliff behavior of mice as a function of genetic differences in eye characteristics. *Psychonomic Science*, 1966, 4, 35-36.
- LINDZEY, G., & WINSTON, H. Maze learning and effects of pretraining in inbred strains of mice. *Journal of Comparative & Physiological Psychology*, 1962, 55, 748-752.
- McCLEARN, G. E. Performance differences among mouse strains in a learning situation. *American Psychologist*, 1958, 13, 405. (Abstract)
- NAGY, Z. M., & FORREST, E. J. Open-field behavior of C3H mice: Effect of size and illumination of field. *Psychonomic Science*, 1970, 20, 19-21.
- NAGY, Z. M., & MISANIN, J. R. Visual perception in the retinal degenerate C3H mouse. *Journal of Comparative & Physiological Psychology*, 1970, 72, 306-310.
- ROSS, S., NAGY, Z. M., KESSLER, C., & SCOTT, J. P. Effects of illumination on wall-leaving behavior and activity in three inbred mouse strains. *Journal of Comparative & Physiological Psychology*, 1966, 62, 338-340.
- SIDMAN, R. L., & GREEN, M. C. Retinal degeneration in the mouse: Location of the rd locus in linkage group XVII. *Journal of Heredity*, 1965, 56, 23-29.
- TANSLEY, K. An inherited retinal degeneration in the mouse. *Journal of Heredity*, 1954, 45, 123-127.
- WIMER, R., & WELLER, S. Evaluation of a visual discrimination task for the analysis of the genetics of a mouse behavior. *Perceptual & Motor Skills*, 1965, 20, 203-208.