Bulletin of the Psychonomic Society
1975, Vol. 5 (2), 117-119

DDT: Effects on maternal behavior

KAREN PAULSEN, VINCENT J. ADESSO and JOHN J. PORTER
University of Wisconsin–Milwaukee, Milwaukee, Wisconsin 53201

To examine the hypothesis that DDT produces hyperexcitability which in turn affects maternal behavior, 14 rats were fed food containing concentrations of DDT. Results showed low DDT (50 ppm) animals exhibited significantly less nursing and greater rejection than the high DDT (100 ppm) and control (0 ppm) groups. It was concluded that poor maternal behavior, and not only DDT ingestion, caused harm to neonates.

Although the physiological effects of DDT poisoning in animals have been examined, no unifying theory is available to explain the observed effects of dichlorodiphenyltrichloroethane (DDT) (Goodman & Gilman, 1970; O'Brien, 1967). There have been few studies of the behavioral effects of DDT. One such study, Sobotka (1971) found that low DDT dosages of up to 25 mg/kg administered to rats increased motor activity and decreased habituation to an open-field situation. Sobotka suggested that DDT interferes with the central inhibitory system, thorough the weakening of the cholinergic system and release of formely inhibited motor activity.

One aspect of DDT-poisoning, that DDT ingested by a pregnant female may cause harm in fetal and natal stages, the later via the mother's milk, has been studied with conflicing results. Fahima, Bennett, and Hall (1970) administered DDT doses of 1, 5, or 25 mg/kg to three groups of nursing rats 24 h after delivery. The manipulation of DDT dosage level resulted in a neonate mortality rate over 21 days of 13%, 32%, and 100%, respectively, compared to 4% for controls. Naishtein and Leibovich (1971), investigating the effect of small doses of DDT on sexual function, found that the weight of newborn rats in all experimental groups was consistently lower than that of the control group for the 28 days of the study. They attribute this lag to the transmission of the pesticides from the mother to the young. Al-Hachim and Fink (1968) suggest that DDT delays the development of the CNS for a few weeks after birth.

There are data that are not consistent with the hypothesis that DDT ingested from the mother's milk causes neonate mortality. Henderson and Woolley (1969) found that three times as much DDT was required to reach LD50 for 10-day-old rats as compared to 60-day-old rats. In addition, Lu, Jessup, and Levallee (1965) has reported an LD50 greater than 4 g/kg for day old rats, 437 mg/kg for 14 to 16-day-old rats and 195 mg/kg for adult rats. Henderson and Woolley indicated that the immature rat is much more resistant to the effects of DDT due to a less efficient nervous system both in that DDT is not absorbed from the blood and a brain less sensitive to DDT's lethal effects. In addition, an examination of the growth table for the pups in the aforementioned Naishtein and Leibovich (1971) study indicated that all animals weighed the same at birth but gradually became more and more disparate over days, possibly due, at least in part, to maternal behavior such as inferior nursing (Paulsen, Adesso, & Porter, 1973).

Taken together these latter data suggest that it may be the behavior of the DDT-poisoned mothers that adversely affects the neonate and not direct ingestion of DDT through the mother's milk by the neonate. An experiment done at Patuxent Wildlife Research Center (Farney, 1971) found that DDT administered to hawks produced thin-shelled eggs as well as abnormal parental behavior such as devouring their eggs or young. Treon, Boyd, Berryman, Gosney, Hartman, Brown, and Coomer (1954) report that DDT did affect mortality during the suckling period while it had no significant effect on number of pregnancies, litter weight, or litter number in rats. Paulsen et al. (1973) found that rat mothers treated with DDT exhibited inferior nest building and retrieval, less nursing time, and more activity than a control animal. Mean weights for the DDT litters were less than those of the controls.

The present experiment was designed to determine whether ingestion of DDT by the neonate is the only cause of mortality or whether the hyperexcitability of DDT-poisoned mothers (Goodman & Gilman, 1970; O'Brien, 1967) may cause poor maternal behavior, also leading to death of the newborns.

METHOD

Subjects

Twenty-four 90 to 100 day old, 250 g 1-week-pregnant primiparous albino rats were obtained from the Holtzman Company of Madison, Wisconsin. The subjects were randomly assigned to three groups of eight and fed dosages of DDT (20% o'p' and 80% p'p' form) dissolved in pure peanut oil mixed with milled rat food as follows: Group 0, 0 ppm; Group 50, 50 ppm; and Group 100, 100 ppm in mg/kg body weight. Water was provided add lib and subjects were fed 10 g of the food mixture per day for 2 weeks' preparturition. Immediately post partum, all subjects were put on an ad-lib diet of Noyes pellets.

Karen Paulsen is now at Southern Illinois University.
Requests for reprints should be sent to Vincent J. Adesso, University of Wisconsin-Milwaukee, Department of Psychology, Milwaukee, Wisconsin 53201.

Table 1
Individual Nursing Time* for Groups 0, 50, and 100 Over Weeks 1 and 2

DDT Dosage	Subject	Week 1	Week 2	Total
0/ppm	1	233	127.5	360.5
	2	239.5	156	395.5
	3	240.75	146.5	387.25
	4	237.5	200	437.5
	5	178.5	86.75	265.25
	6	200.25	162	362.25
	7	218	82	300
	8	255.25	136.5	391.75
50/ppm	1	40	0	40
	2	221.25	103.5	324.75
	3	110.75	70	180.75
	4	217	134	351
	5	132	61.5	193.5
	6	155.5	102	257.5
	7	142	75.25	217.25
	8			
100/ppm	1	206.5	153.8	360.3
	2	212	149	361
	3	145	182.2	327.2
	4	174	91	265
	5	205.5	121.75	327.25
	6			
	7	228.5	150.5	379
	8			

**Number of minutes spent nursing during observation periods.*

Apparatus

The subjects were housed one per cage in 76 x 76 x 25 cm wood and wire mesh observation cages. Cage floors were marked off into 15 x 15 cm squares. Lights in the observation room were on a 12-h day-night cycle, set at 7:30 am and pm. Five days preparturition, nest building material was provided.

Procedure

Rejection (defined as number of pups consumed), amount of time spent nursing, and activity (defined as number of floor squares crossed) were observed for 10 min, four times per day at 8, 11 am, and 2, and 5 pm for 2 weeks post partum, the period during which all normal females continue to engage in maternal behavior (Beach, 1937; Rosenblatt & Lehrman, 1963; Stone, 1938). The size of the litters was manipulated to 4 to 8 pups per mother through randomly switching pups across groups so that each litter had control and DDT pups.

RESULTS AND DISCUSSION

Each group had an average of approximately five pups per litter. There was nonsignificant difference between the groups in litter size, $F(2,19) < 1$.

A total of 16 pups was consumed by Group 50, and 5 each for Groups 0 and 100. A chi-square analysis of these data revealed that significantly more pups were consumed by Group 50 and less than expected by Groups 0 and 100 based on the proportion of pups in each respective group to the total number of pups, $\chi^2(2) = 9.37, p < .01$.

The loss of one subject in Group 100 and one subject in Group 50 led to a least-squares analysis (Kirk, 1968) of the nursing data since these subjects had consumed their pups immediately after birth. The analysis of the nursing data revealed a significant main effect of dosage [$F(2,18) = 7.53, p < .01$]. Using Tukey's HSD test (Kirk, 1968) it was found that there was significantly less nursing by Group 50 (mean = 223.54) than Groups 100 and 0 (means = 336.63 and 362.5, respectively), the latter two groups did not differ significantly. As is apparent in Table 1, nursing decreased for all subjects over weeks [$F(1,18) = 81.15, p < .01$].

The loss of one nonpregnant subject in Group 100 led to an unweighted means analysis of the activity data, and showed a significant increase in activity over weeks [$F(1,20) = 14.54, p < .01$]. The pronounced increase in activity over successive days of Group 0, apparent in Table 2, seemingly washed out any cumulative DDT effect [$F(2,20) = 2.7, .05 < p < .10$].

The behavior of Group 50 appears to be a result of hyperexcitability induced by DDT (Goodman & Gilman, 1970; Sobotka, 1971), and the data also indicate that very high concentrations of DDT (Group 100) cause prostration (O'Brien, 1967). This latter observation is the suggested explanation of the observed nonlinear relationship between dosage of DDT and activity. The activity for Group 50 was relatively high during Weeks 1 and 2, while the activity of Group 100 remained relatively low. Group 0 exhibited normal weaning behavior in that activity was low during the first week but gradually increased during Week 2.

The data further suggest that the hyperexcitability

Table 2
Individual Activity* for Groups 0, 50, and 100 Over Weeks 1 and 2

DDT Dosage	Subject	Week 1	Week 2	Total
0/ppm	1	218	202	420
	2	259	356	615
	3	268	641	909
	4	318	1234	1552
	5	414	550	964
	6	373	488	861
	7	316	626	942
	8	130	808	938
50/ppm	1	249	256	505
	2	272	396	668
	3	369	349	718
	4	321	486	807
	5	619	836	1455
	6	1210	1588	2798
	7	729	451	1180
	8	246	325	571
100/ppm	1	412	432	844
	2	387	508	895
	3	187	304	491
	4	338	487	825
	5	335	574	909
	6	109	178	287
	7	275	381	656
	8			

**Defined as number of squares crossed.*

effect of DDT upon Group 50 contributed to significantly less nursing activity than in Groups 0 and 100. Also, Group 100, rather than being hyperexcitable, was prostrated by the DDT and thus remained in the nest and nursed.

Further evidence for the hyperexcitability-prostration interpretation is provided by the rejection data. Poor mothering by the animals in Group 50 led to the death of significantly more pups than expected based on the proportion of pups in Group 50 to the total number of pups. The switching of pups across litters renders an alternate interpretation of degree of pup DDT content as an explanation of pup consumption untenable. It should be mentioned that while many of the pups in Group 50 were allowed by the mothers to expire via nonnursing and nonretrieval, cannibalism of healthy pups was also observed.

In conclusion, the data of the present experiment would appear to support the hypothesis that poor maternal behavior, and not only direct ingestion of DDT, may cause harm to neonates.

REFERENCES

Al-Hachim, J. G., & Fink, G. B. Effect of DDT or Parathion on open-field behavior of offspring from DDT- or Parathion-treated mothers. Psychological Reports, 1968, 22, 1193-1196.

Beach, F. A. The neural basis of innate behavior: I. Relative effects of cortical lesions upon the maternal behavior pattern in the rat. Journal of Comparative Psychology, 1937, 24, 393-440.

Fahim, M. S., Bennett, R., & Hall, D. G. Effect of DDT on the nursing neonate. Nature, 1970, 228, 1222-1223.

Farney, D. New hope at Patuxent. National Wildlife, 1971, 9, 45-47.

Goodman, L. S., & Gilman, A. *The pharmacological basis of therapeutics.* New York: McMillan, 1970.

Henderson, G. L., & Woolley, D. E. Studies on the relative insensitivity of the immature rat to the neurotoxic effects of 1, 1, 1, -Trichloro-2, 2-Bix (p-Chlorophenyl) ethane (DDT). Journal of Pharmacology & Experimental Therapeutics, 1969, 170, 173-180.

Kirk, R. E. *Experimental design: Procedures for the behavioral sciences.* Belmont, Cal: Brooks/Cole, 1968.

Lu, F. C., Jessup, D. C., & Levallee, A. Toxicity of pesticides in young vs. adult rats. Food and Cosmetic Toxicology, 1965, 3, 591-596.

Naishtein, S. Y., & Leibovich, D. L. Effect of small doses of DDT and lindane and their mixture on sexual function and embryogenesis in rats. Gigiena I Sanitariia, 1971, 36, 190-195.

O'Brien, R. D. *Insecticides: Action and metabolism.* New York: Academic Press, 1967, Pp. 108-135.

Paulsen, K., Adesso, V. J., & Porter, J. J. Report on pilot study of effect of DDT on maternal behavior. Bulletin of the Psychonomic Society, 1973, 1, 205-206.

Rosenblatt, J. S., & Lehrman, D. D. Maternal behavior of the laboratory rat. In H. L. Rheingold (Ed.), *Maternal behavior in mammals.* New York: Wiley, 1963, Pp. 8-54.

Sobotka, T. J. Behavioral effects of low doses of DDT. Proceedings of the Society for Experimental Biology & Medicine, 1971, 137, 952-955.

Stone, C. P. Effects of cortical destriction on reproductive behavior and maze learning in albino rats. Journal of Comparative Psychology, 1938, 26, 217-236.

Treon, F. J., Boyd, J., Berryman, F., Gosney, J., Hartman, L., Brown, D., & Coomer, J. Final report. Kettering Laboratory, University of Cincinnatti, College of Medicine, 1954.

(Received for publication November 14, 1974.)

Bulletin of the Psychonomic Society
1975, Vol. 5 (2), 119-121

Anagram solution times, word length, and type of accessory clue

D. J. MURRAY and L. L. MASTRONARDI
Queen's University, Kingston, Ontario, Canada

Previous research on long-term memory has shown that the number of items retrieved is a power function of the number presented. An application of this power law to the prediction of anagram solution times as a function of word length was, in general, successful. It was also found that giving semantic cues decreased solution time more than did giving graphemic cues.

Studies on the retrieval of items such as words or pictures have shown, that, if P items are presented, and R are retrieved, then

$$R = k\,P^m \qquad (1)$$

where k and m are parameters to be found empirically (Standing, 1973; Murray, in press). The question asked in the present work was whether a similar formula could be applied in determining how long it takes to solve an anagram. It seems likely that in solving an anagram the subject processes a number of permutations of the letters of the anagram until he eventually finds a

This paper is sponsored by P. C. Dodwell, who takes full editorial responsibility for it.