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Journal

Developmental Psychobiology, 4

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Publication Date

1971

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Environmentally Induced Changes in the Dimensions of the Rat Cerebrum

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Walsh, Roger N., Budtz-Olsen, Otto E., Torok, Amelia, and Cummins, Robert A. (1971). *Environmentally Induced Changes in the Dimensions of the Rat Cerebrum*. DEVELOPMENTAL PSYCHOBIOLOGY, 4(2): 115-122. Two groups of rats were reared under conditions of environmental complexity while their littermates were reared in isolation. Cerebral length and width were measured following 30 and 80 days of differential rearing. In the 30-day group differences in neither cerebral length nor width reached significant levels but the product of the 2 parameters was 2.1% ($p < .02$) greater in the stimulated animals. In the 80-day group cerebral length was significantly greater ($p < .001$) in the stimulated animals than in their isolated littermates, but no significant differences in cerebral width were detected.

environmental complexity isolation cerebral dimensions
brain weight laboratory rat

Several forms of environmental stimulation have been shown to be capable of eliciting changes in brain morphology. Over the last decade Rosenzweig, Bennett, Diamond, Wu, Slagle, and Saffran (1969) have investigated the effects of environmental complexity, blinding, and rearing under several conditions of illumination, on cerebral morphology and biochemistry. Environmental complexity has been most closely studied and has been found to cause changes in cortical weight and thickness, neuroglial numbers, perikaryonal size, and activity of the cholinesterase enzyme systems. Similar changes in thickness and neuroglial numbers have been reported for the hippocampus by Walsh, Budtz-Olsen, Penny, and Cummins (1969).

Recently Altman, Wallace, Anderson, and Das (1968) found that antero-posterior growth of the rat cerebrum continues into adulthood, and that this growth is modifiable by environmental stimulation. These workers reported that 4 months of operant conditioning on pattern discrimination tasks, 3 months of rearing in an enriched environment, or 10 days of daily handling during infancy all led to increased cerebral length. The aim of the present study was to extend the investigation of the effects of an enriched environment on cerebral dimensions using varying durations of differential rearing and a different strain of rat. While this work was being completed, Rosenzweig and Bennett (1969) reported that in contradistinction to Altman *et al.* (1968) they were unable to detect any increase in the length of rat or gerbil cerebri following rearing in an enriched environment. The results of the present study may offer an explanation of this apparent contradiction.

Method

Male rat pups of the Wistar strain (*Rattus norvegicus*) were weaned at about Day 25. Littermates were matched for weight; one animal of each pair was assigned to conditions of environmental complexity and the other isolated.

The environmental conditions were similar to those previously described by Walsh *et al.* (1969). Animals reared in a complex environment were housed in groups of 10 in. wire mesh cages $9 \times 9 \times 18$ in., and 6 different "toys" from a collection of 30 were placed in the cages each day. Isolated rats were housed in individual cages $5 \times 7 \times 12$ in. with smooth metal walls, which were placed in a separate room away from much of the noise and incidental activity of the animal house. Two groups of animals were differentially reared as described for 30 and 80 days, and the brains of 19 and 18 littermate pairs, respectively, were examined.

At the conclusion of the differential rearing period (at 55 days of age for the 30-day group and 105 days for the 80-day group) the animals were anesthetized, then killed by decapitation and the brains were removed, weighed, and

placed in 10% formol saline within 10 min of death. Weighing was performed on a Mettler balance accurate to .1 mg. The whole brain minus the olfactory lobes was weighed first and the brain then sectioned coronally at the level of the posterior pole of the cerebral cortex. The anterior component thus obtained consisted of the forebrain and the greater part of the midbrain, whereas the posterior component consisted of hindbrain and the remaining midbrain. After 1 week of fixation, the length (from anterior to posterior pole) and greatest width of the cerebral hemispheres were determined using a verier scale at a magnification of $\times 12.5$. Measurements were repeated after a further week yielding a Spearman correlation coefficient of .81. The mean value of each was used for statistical analyses.

Results

Although originally matched for body weight, the isolated animals were significantly heavier than their littermates within 1 week of initiating the differential rearing. At the conclusion of the experiment this difference amounted to 21.4% ($p < .001$) for the 30-day group and to 19.3% ($p < .001$) for the 80-day animals. Brain weights showed no significant differences between littermates except in the 80-day group where the ratio of the weight of the forebrain + midbrain component to that of the hindbrain (F + M : H) was 3.66% greater ($p < .05$) in the subjects reared in the complex environment (Tables 1 and 2).

Examination of Tables 3 and 4 reveals significant littermate differences in cerebral dimensions. In the 30-day group differences in both cerebral length and width failed to reach the .05 significance level, but their product was 2.1% ($p < .02$) greater in the animals reared under conditions of environmental complexity. Following 80 days of differential treatment, cerebral length and the product and ratio of cerebral length and width, but not cerebral width alone, showed significant differences ($p < .001$) between littermates.

Discussion

Whereas it is not possible to determine the time course of the differential rearing effect from the data presently available, changes in cerebral length were clearly detectable at 90 days (Altman *et al.* 1968) and in the present study after 80 days, but failed to reach significant levels after 30 days. Rosenzweig, Bennett, and Diamond (1967) have analyzed the cerebral changes induced by differential experience of varying durations and a variety of temporal patterns have been identified. Transient components of cerebral weight have been identified in all cortical areas except the occipital, and transient components of environmentally-

TABLE 1. Brain weights (g) following 30 days of differential rearing ($N = 19$ for each group).

		Total Brain	Forebrain + Midbrain	Hind- brain	F + M : H
Environmental complexity	Mean	1.6352	1.2432	0.3920	3.1805
	S.D.	0.1022	0.0837	0.0288	0.2251
Isolation littermates	Mean	1.6271	1.2419	0.3852	3.2391
	S.D.	0.0861	0.0720	0.0297	0.2663
% Difference		0.5	0.1	1.76	-1.81
		N.S.	N.S.	N.S.	N.S.
Correlation between littermates		.75	.78	.27	.20

TABLE 2. Brain weights (g) following 80 days of differential rearing ($N = 18$ for each group).

		Total Brain	Forebrain + Midbrain	Hind- brain	F + M : H
Environmental complexity	Mean	1.7037	1.2505	0.4527	2.7702
	S.D.	0.0657	0.0587	0.0228	0.1890
Isolation littermates	Mean	1.6865	1.2263	0.4602	2.6724
	S.D.	0.0966	0.0726	0.0332	0.1673
% Difference		1.02	1.97	-1.63	3.66
		N.S.	N.S.	N.S.	< .05
Correlation between littermates		.45	.45	.34	.39

induced cerebral acetylcholinesterase activity, though less clearly marked, appear to occur throughout the cortex. Permanent and transient histological correlates of differential experience have been noted by Gyllenstein, Malmfors, and Norrlin (1965) who found differences between the occipital cortices of light- and dark-reared mice for cortical thickness, nuclear diameter, and the volume of inter-nuclear material per nucleus. In the light of these findings a more extensive temporal analysis of environmentally-induced changes in cerebral length might reveal any one of a number of possible time courses.

The fact that the littermate difference in the ratio of the weight of the forebrain plus midbrain to that of the hindbrain should reach significant levels in

TABLE 3. Cerebral dimensions (mm) following 30 days of differential rearing ($N = 19$ for each group).

		Length (L)	Width (W)	Product L x W	Ratio L:W
Environmental complexity	Mean	14.3	16.16	231.0	0.88
	S.D.	0.56	0.35	12.1	0.032
Isolation littermates	Mean	14.1	16.02	226.0	0.88
	S.D.	0.42	0.43	11.5	0.023
% Difference		1.3	0.9	2.2	0
		N.S.	N.S.	< .02	N.S.
Correlation between littermates		.56	.60	.70	0

TABLE 4. Cerebral dimensions (mm) following 80 days of differential rearing ($N = 18$ for each group).

		Length (L)	Width (W)	Product L x W	Ratio L:W
Environmental complexity	Mean	14.93	15.88	237.1	0.94
	S.D.	0.42	0.40	9.3	0.034
Isolation littermates	Mean	14.58	15.82	230.7	0.92
	S.D.	0.27	0.37	7.7	0.023
% Difference		2.5	0.3	2.8	2.2
		< .001	N.S.	< .001	< .02
Correlation between littermates		.46	.40	.51	.30

the 80-day group is interesting since we have noted similar findings following 90 days of differential rearing (R. N. Walsh, O. E. Budtz-Olsen, & R. A. Cummins, unpublished data). Furthermore Zolman and Morimoto (1965) and Rosenzweig *et al.* (1967) have found the ratio of cortical to subcortical weight to be one of the brain parameters most sensitive to environmental modification.

The results obtained from measurement of the length and width of the cerebrum offer support to the conclusions of Altman *et al.* (1968) that cerebral length is susceptible to environmental modification, but that cerebral width does not change. No differences in cerebral width have been detected after 90, 80, or 30 days, and so it is doubtful what significance can be attached to the finding of

an increased value for the product of cerebral length and width in the 30-day animals reared under conditions of environmental complexity (Table 3). Since Altman *et al.* (1968) employed Long-Evans hooded rats and we used Wistar strain animals in the present study, it would seem that the environmental effect on cerebral length is not strain specific.

The failure of Rosenzweig and Bennett (1969) to detect an influence of environmental complexity on brain length of rats and gerbils may be due to at least two factors. Firstly, the animals were differentially reared for only 30 days, a period which we have found insufficient to elicit a significant change. Secondly, differential rearing of rats was initiated 60 days after birth, by which time the growth rate of cerebral length had slowed considerably. If, as suggested by Altman *et al.* (1968), changes in brain length brought about by stimulation act by modifying early postnatal growth, and if the magnitude of the cerebral response is a function of the unstimulated growth rate, then it might be expected that environmentally-induced changes after 60 days of age would be small.

Altman *et al.* (1968) were unable to single out the environmental factors which may have contributed to the enhancement of cerebral length. However, Rosenzweig *et al.* (1969) demonstrated that visual experience is not a necessary component of exposure to environmental complexity for the induction of changes in the occipital and other cortical regions, since they observed that significant differences arise between littermates maintained in either enriched or impoverished conditions even if the animals are blinded or kept in total darkness. It has also been found (Krech, Rosenzweig, & Bennett, 1960; Zolman and Morimoto, 1965) that differences in locomotion, handling, or a combination of these factors do not appear to be involved in the production of the cerebral changes observed by these workers. Whether any of the above-mentioned factors are involved in the increase in cerebral length remains to be determined.

A greater increase in the body weight of isolated animals has been a common finding (Bennett, Diamond, Krech, & Rosenzweig, 1964; Krech *et al.*, 1960; Zolman and Morimoto, 1962, 1965) and this has led to the idea that the body weight varies inversely with the amount of stimulation (Krech, Rosenzweig, & Bennett, 1966). However, some workers have found either a decrease in the isolated body weight (Geller, Yurvilier, & Zolman, 1965) or no change at all (Giacolone, Tansella, Valzelli, & Garattini, 1968), and recently Henderson (1970) has shown that the effect on body weight may be simply a function of the food availability. This explanation could be applied to the present experiment where differences in food hopper size and social competition for food may have caused the body weight differences, but it seems likely that whatever the explanation of the body weight changes they are large independent of the cerebral length increases observed in the stimulated animals.

Notes

This project was supported by the Australasian Medical Students Association Research Fellowship 1969-1970. The authors wish to thank Mr. D. Gowanlock and Miss A. Richards of the Department of Anatomy, University of Queensland and Mr. A. Stark, Mr. W. R. Fairbanks and Mrs. C. L. Kerslake of Morbid Anatomy, Department of Pathology, Royal Brisbane Hospital for their skilled assistance with histological preparations, Mr. D. Long for assistance with brain measurements and Miss M. Gillett for constructive criticism.

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