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Environmentally Induced Changes in the Dimensions of the Rat Cerebrum: A Replication and Extension

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In previous reports exposure to 80 or 90 days of environmental complexity induced a significant increase in the length of the rat cerebrum, whereas 30 days' exposure induced changes which failed to reach significant levels. In the present study after 30 days of differential rearing, cerebral length was 1.2% ($p < .005$) greater in brains from the enriched animals; the region contributing to this increase lay between the anterior pole and the point of greatest cerebral width. Measurements of cerebral width and brain weight failed to show any significant change, but the body and adrenal weights of the isolated rats were 19.9% ($p < .001$) and 8.8% ($p < .02$) greater, respectively, than those of their littermates reared in environmental complexity. However, the ratios of adrenal weight to body weight did not differ significantly between groups.

Recently Altman, Wallace, Anderson, and Das (1968) demonstrated that the post-natal antero-posterior growth of the rat cerebrum is capable of modification by environmental stimulation. They found that 4 months of operant conditioning, 10 days of daily handling during infancy, and 3 months of rearing in an enriched environment each led to increased cerebral length. This increase was confirmed by Walsh, Budtz-Olsen, Torok, and Cummins (1971) who found the cerebra of enriched animals to be 2.5% ($p < .001$) longer than those of their isolated littermates after 80 days of differential rearing. However, following 30 days of environmental enrichment only a 1.3%

(n.s.) difference could be found, a result very similar to that of Rosenzweig and Bennett (1969) who reported a 1% (n.s.) change following a similar 30 day period. Whether this increase represented a significant treatment effect, and if so whether the increase occurred throughout the cerebrum or exhibited a degree of region specificity should be determined.

Method

The differential rearing procedure has previously been described in detail (Walsh et al. 1971) and only a summary will be given here. Forty-four male Wistar rats (*Rattus norvegicus*) from a random bred strain maintained in the University of Queensland Animal Centre were weaned at Day 25 and littermates were matched for body weight. One animal of each pair was assigned to conditions of environmental complexity, obtained by the daily addition of 'toys' to a group cage, while its littermate was isolated. After 30 days of differential rearing (at 55 days of age), the animals were weighed, killed by decapitation, and the wet weights of the brains and dry weights of the adrenal glands were determined. The brain minus the olfactory lobes was weighed and then sectioned transversely at the level of the posterior pole of the cerebral cortex, thereby yielding an anterior component which consisted of forebrain and the greater part of the midbrain, and a posterior component of hindbrain and the small remainder of the midbrain. After 1 week of fixation in 10% formal-saline cerebral dimensions were measured using a dissecting microscope at a magnification of 12.5. Cerebral width was determined at 2, 4, 6, and 8 mm from the anterior pole, at the region of greatest cerebral width, and 2 mm rostral to the posterior pole. Cerebral length was measured from the anterior and posterior poles of the cortex to the region of greatest cerebral width, thus giving the lengths of the cerebrum both anterior and posterior to this region, as well as the total length. Measures were repeated after a further 2 weeks of fixation, yielding a reliability coefficient of .96. Animals were delivered to the laboratory under code numbers so that all measurements were made without knowledge of the experimental group from which each animal was derived.

Results and Discussion

The significance of treatment effects on each parameter were calculated by the use of Student's *t*-test for matched subjects. The results for cerebral dimensions were similar to those of the previous study (Walsh et al., 1971) with cerebral length being 1.2% ($p < .005$) greater in the enriched animals (Table 1). Combining these findings with those of the previous study indicates a mean increase in cerebral length of 1.25% ($p < .002$). Apparently, the cerebral component contributing to this increase lies anterior to the region of maximum cerebral width since the length of this component was 2.6% ($p < .02$) greater in the enriched animals whereas the posterior region showed

TABLE 1. Length and Maximum Width of the Cerebrum (mm) (N=22 pairs) after 30 Days of Differential Rearing

Cerebral Dimensions (mm)	Environmental Complexity		Isolation Littermates		Percent Difference	p
	Mean	S.D.	Mean	S.D.		
Total Length	13.84	0.26	13.67	0.255	1.2	<.005
Anterior Length Component	10.14	0.394	9.92	0.266	2.6	<.02
Posterior Length Component	3.70	0.294	3.75	0.211	-2.4	n.s.
Maximum Width	15.37	0.363	15.38	0.453	-.1	n.s.

no significant change (-2.4%, n.s.). Cerebral width remained unchanged in all those areas which were measured; the ratio and the product of cerebral length and cerebral width also showed no change. Brain weights also showed no significant treatment effects.

In their original observation of behaviorally induced changes in length of the rat cerebrum, Altman et al. (1968) drew attention to the presence of a mitotically active subependymal layer present in the anterior part of the forebrain of adult rats, from which cells migrate to the anterior forebrain (cortex and basal ganglia) (Altman, 1963, 1966; Altman and Das, 1966). If modification of the activity of this layer underlies changes in cerebral dimensions these changes may be localized to the anterior regions of the cerebrum. The finding that the increase in cerebral length occurs anterior to the region of maximum cerebral width supports this hypothesis. However no change could be detected in the width of the anterior cerebral regions examined.

The increase in cerebral length induced by 30 days of differential rearing (1.25%) appears to be only half that induced by an 80 day period (2.5%) whereas changes induced in other morphological characteristics, e.g., cortical depth, cortical weight and neuronal size, appear to reach a maximum within 30 days after which, with the exception of the occipital cortex, they partially diminish (Rosenzweig, Bennett, Diamond, 1967; Rosenzweig, Bennett, & Diamond, 1971).

As in the previous study the isolated animals were significantly heavier than their littermates (19.9%, $p < .001$) at the conclusion of the experiment (Table 2). The adrenal weights were also greater in the isolates (9.6%, $p < .02$) but the ratio of adrenal to body weight was greater in animals from the complex environment (11.4%, n.s.). The correlation coefficient between adrenal and body weights did not reach significant levels in either enriched or isolated animals (.28 and .21, respectively).

The occurrence of greater adrenal and body weights among the isolated rats has been a consistent finding both in this laboratory and in that of Rosenzweig and his co-workers (Krech, Rosenzweig, & Bennett, 1966; Rosenzweig & Bennett, 1969). The adrenal response to environmental stimulation appears to be a function of the interaction of a large number of variables (Ader, Friedman, & Grotta, 1967; Bush, 1962;

TABLE 2. *Body and Adrenal Weights after 30 Days of Differential Rearing (N=22 pairs)*

	Environmental Complexity		Isolation Littermates		Percent Difference	p
	Mean	S.D.	Mean	S.D.		
Body Weights (g)	119	21.4	142	26.3	19.9	<.001
Adrenal Weights (mg)	125.7	27.82	137.8	23.66	9.6	<.02
Adrenal Weight: Body Weight X 1000	1.101	0.2902	0.988	0.2304	11.4	n.s.

Christian, Lloyd, & Davis, 1965) but the fact that the adrenal weight:body weight ratio did not differ significantly would seem to indicate an agreement with Rosenzweig and Bennett who suggested that the increased adrenal weight is secondary to the greater body weight.

Notes

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