THE EFFECTS OF EARLY DIFFERENTIAL ENVIRONMENTS ON PHOTIC EVOKED POTENTIALS. AROUSAL AND BEHAVIOUR OF THE MONGOLIAN GERBIL

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Thesis presented to the Faculty of
Psychology of the University of
Ottawa as partial fulfillment of the
requirements for the degree of
Master of Arts

Ottawa, Canada, 1970

RECEIVED AUG - 4 1970

ACKNOWLEDGMENTS

This thesis was prepared under the supervision of Dr. Henry P. Edwards, Ph.D., Assistant Professor at the Faculty of Psychology of the University of Ottawa.

The writer is indebted to Mr. E. Achorn, Computer Technician, and Mr. R. Spratt, Laboratory Technician at the Department of Psychophysiology of the University of Ottawa for their continued interest and help in the technological aspect of the research. The writer also expresses his gratitude to Mr. B. Willis for his assistance during the experimental session.

CURRICULUM STUDIORUM

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INTRODUCTION

A number of investigators at the University of Ottawa have reported a significant relationship between Photic Evoked Potentials and human intellectual efficiency as measured by conventional psychometric tests. Such a relationship, if substantiated through a series of interlocking studies may point to a "rapprochement" between behavioural intelligence and its possible physiological counterpart as reflected in Photic Evoked Potentials.

The present investigation represents an outcome of previous animal studies at the University of Ottawa concerning the effects of differential early stimulation on both physiological and behavioural measures in the albino rat, keeping initial constitutional differences to a minimum.

The present writer's experiment is thus designed as a partial replication and extension of previous findings, but now with the Mongolian gerbil as subject. More specifically, the author wishes to investigate whether animals raised in enriched environments will display different Photic Evoked Potential waveforms after two months of differential post-weaning rearing, be better learners and exhibit less exploratory, arousal and emotional behaviour than environmentally deprived animals.

INTRODUCTION

The first chapter of this thesis presents a review of the pertinent literature. It considers briefly studies relating psychometric intelligence and Photic Evoked Potentials, the possible link between these physiological measures and arousal as well as the effects of differential environments on learning ability and exploratory tendencies. Further sections examine the anatomical and chemical counterparts of differentially reared animals and present related theoretical considerations and experimental evidence. The following sections discuss sensory deprivation and enrichment with respect to emotionality and Evoked Potentials whereas the final section considers recent views concerning the use of the Mongolian gerbil in behavioural research.

The second chapter describes and illustrates the experimental procedure and the statistical analysis employed to test the research hypotheses.

The final chapter presents the statistical results of the experiment and discusses them.

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CHAPTER I

REVIEW OF THE LITERATURE

A number of researchers at the University of Ottawa have reported significant correlations between Photic Evoked Potentials and measures of intellectual efficiency, both with humans and animals. Such a relationship indicating concomitance of behavioural and physiological phenomena appears worthy of further investigation and interdependent research. It is also believed that the captivating nature-nurture issue in the area of intelligence and behaviour also warrants further experimental effort.

In this context, the present study wishes to re-examine previous research evidence concerning the effects of early differential environments on particular behavioural and physiological tests, including the Photic Evoked Potential. The major theoretical framework that generated the present study is that of Ronald Melzack.

This chapter reviews the literature on the observed relationship between intelligence and Photic Evoked Potentials, various comments concerning arousal as well as studies concerning early differential rearing in relation to learning, exploration and resulting chemical-anatomical differences. Related theoretical and research viewpoints are also presented. The later sections focus upon the area of sensory deprivation and enrichment in relation to the variables of emotionality and Evoked Potentials. A short presentation of behavioural data concerning the Mongolian gerbil precedes the presentation of the working hypotheses.

1. Evoked Potentials and Psychometric Intelligence.

The technique of Evoked Potentials consists of the random presentation of discrete stimuli (flashes of light for example) and the algebraic summation by a computer of the time-locked brain activity.

The early work of Ertl[1] at the University of Ottawa attempted to relate intra-cortical delay[2] to network efficiency and biological intelligence. It was hypothesized that the shorter the central delay in responding to a given stimulus, the greater the efficiency of the organism, that is, the more intelligent. In this study, a negative correlation of -0.88 was observed between Photic Evoked Potential[3] latencies and

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[1] J.P. Ertl, Intra-Cortical Delay and Intelligence, unpublished Master's thesis presented to the School of Psychology and Education of the University of Ottawa, Ontario, 1961, viii-41 p.

[2] Intra-cortical delay was defined as the time required for information to be assimilated and propagated from one area of the brain to another.

[3] Hereafter referred to as PEP; EP denotes Evoked Potential.

intelligence scores. In 1966, Taylor[4] found a correlation of -0.68 significant at the .01 level between the PEP latency of the third event and overall I.Q. scores on the Otis test.

In the light of theoretical and experimental considerations, Chalke and Ertl formulated the following rationale:

> It is known that there is considerable inter-individual variability and intra-individual consistency in the latency of evoked potentials. It is generally believed that the late components of the evoked potentials are the electrical signs of information processing or associative activity in the brain. From this it is reasonable to postulate that a biologically efficient organism should process information more rapidly than a less efficient organism and that the delay of components of the evoked potentials is a measure of the efficiency of this process.[5]

In their sample of thirty-three postgraduate students with superior I.Q., 11 army cadets of low average I.Q. and 4 mental retardates of inferior I.Q., the authors again noted that the more intelligent subjects displayed substantially shorter latencies in the late components of the PEP as compared to their less intelligent subjects. No differences were found in the early components of the waveform. In a further

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[4] N. Taylor, Evoked Potential Latencies and Psychometric Intelligence, unpublished Master's thesis presented to the School of Psychology and Education of the University of Ottawa, Ontario, 1966, ix-76 p.

[5] F.R. Chalke and J.P. Ertl, "Evoked Potentials and Intelligence", Life Sciences, Vol. 4, No. 13, 1965, p. 1319.

sample of 573 low and high I.Q. children, Ertl and Schafer[6] found that the third and fourth peaks of the PEP waveform correlated at the .001 level with Otis, PMA and WISC intelligence scores.

In this context, it appears of interest to see whether a subject's environment exercises an appreciable influence on photic evoked responses when constitutional differences between subjects are kept basically constant. Such a longitudinal study is, of course, possible with animal subjects.

2. Evoked Potentials and Arousal.

Human EP studies have generally emphasized the relationship between such factors as attentiveness level, signal detection, heightened arousal and EP amplitude.

Haider *et al*.[7] report an overall trend between vigilance decrement and EPs. The EPs to signals which a subject failed to detect, thus indicating reduced attentiveness, were typically reduced in amplitude as compared with those of equal number of signals which were correctly detected. Donchin and Lindsley[8]

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[6] J.P. Ertl and E.W.P. Schafer, "Brain Response Correlates of Psychometric Intelligence", *Nature*, Vol. 223, 1969, p. 421-422.

[7] M. Haider, P. Spong and D.B. Lindsley, "Attention, Vigilance and Cortical Evoked Potentials in Humans", *Science*, Vol. 145, 1965, p. 182.

[8] E. Donchin and D.B. Lindsley, "Average Evoked Potentials and Reaction Times to Visual Stimuli", *EEG and Clinical Neurophysiology*, Vol. 20, 1966, p. 222.

state that the greater the alertness involved in a situation, the greater the amplitude of the EP, possibly enhanced by the non-specific arousal and alerting mechanism. Mackworth[9] has also found that if the actual event agrees with the predicted event, then the neural responses to this event are reduced (lowered amplitude of EP) but if the actual event differs sufficiently from the predicted event, then the neural response is augmented (heightened amplitude of EP). Spong and Lindsley[10] found that responses were of much greater magnitude during a discrimination task requiring substained attention than during either pressing or passive tasks. The general finding was that the amplitude of the long latency EP components was positively related to attentiveness level.

Animal EP studies report a similar trend. Speaking of the rat EP, Kimura says, "This response is labile and sensitive to the arousal level of the animal."[11]

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[9] J.F. Mackworth, "Vigilance, Arousal and Habituation", Psychological Review, Vol. 75, No. 4, 1968, p. 308.

[10] P. Spong and D.B. Lindsley, "Cortical Evoked Responses and Attentiveness in Man: Differential Effects of Selective Attentiveness and General Alertness Level", Western Society of Electroencephalography Proceedings, EEG and Clinical Neurophysiology, 1968, p. 397.

[11] D. Dimura, "Multiple Response of the Visual Cortex of the Rat to Photic Stimulation", EEG and Clinical Neurophysiology, Vol. 14, 1962, p. 121.

Pickenhain and Klingberg[12] found that the amplitudes of EPs diminished during motor activity of the rats, especially during orienting movements. On the contrary, they were increased when the animal, fully awake, did not move, especially during a tense posture. The authors explain the decrease of amplitude of the EP in the disturbance phase on the basis of an excessive non-specific activation and believe that the decrease reflects the fact that in this phase of excessive non-specific activation fewer cortical neurons are available for synchronized discharges. With several repetitions of the new situation, the excessive non-specific activation is more and more limited. Thus more cortical neurons are available for synchronized discharge and hence the larger the EP amplitude.

Steinberg,[13] using cats as subjects, has shown that during prolonged repetititve photic stimulation with changes in arousal level, the mean amplitude of all deflections, exclusive of the initial short latency response increased during sleep and decreased during arousal, and the mean latency of the initial deflection was decreased during

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[12] L. Pickenhain and F. Klingberg, "Behavioural and EEG Changes During Avoidance Conditioning to Light Flashes in the Rat", EEG and Clinical Neurophysiology, Vol. 18, 1965, p. 467, 471.

[13] R.H. Steinberg, "Alterations of Averaged Photic Evoked Potentials in Cat Visual Cortex During Repetitive Stimulation", EEG and Clinical Neurophysiology, Vol. 18, 1965, p. 390.

arousal. Schwartz and Shagass[14] also report a decrease in amplitude with increasing arousal. Shaw and Thompson[15] studied EPs to auditory, visual and tactile stimulation recorded from the posterior association cortex in the normal waking cat and again found that the amplitudes to all modalities of stimuli decreased during bodily activity and during novel stimulation of any modality. In a subsequent study,[16] these same authors hypothesized that amplitudes of evoked cortical association responses would be inversely related to degree of "attention", operationally defined as the extent of behavioural orienting to a stimulus. Cats with implanted cortical recording electrodes were given a series of clicks through either of two oppositely placed speakers. The degree and accuracy of the orienting response were rated, and the evoked cortical association response simultaneously recorded, for each click. As predicted, the degree of the orienting response decreased significantly over trials, while the amplitude of the evoked association response exhibited a concomitant increase over trials. Thus, one would expect

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[14] M. Schwartz and C. Shagass, "Effects of Different States of Alertness on Somatosensory and Auditory Recovery Cycles", EEG and Clinical Neurophysiology, Vol. 14, 1962, p. 11.

[15] J.A. Shaw and A.F. Thompson, "Dependence of Evoked Cortical Association Responses on Behavioral Variables", Psychonomic Science, Vol. 1, 1964, p. 153.

[16] ----------, "Inverse Relation Between Evoked Cortical Association Responses and Behavioral Orienting to Repeated Auditory Stimuli", Psychonomic Science, Vol. 1, 1964, p. 399-400.

that more aroused animals would display lower PEP amplitudes than less aroused animals.

3. Early Differential Environment, Learning and Exploration.

Most of the work done on sensory deprivation and enrichment represent an outgrowth of Hebb's experiments and theorizing. In one of the first publications on the topic, Hebb[17] compared animals blinded at birth with others blinded at maturity and also compared animals reared to maturity in cages with others which were allowed frequent exploration of a varied environment. The superiority of the group with the greater infant experience was established and Hebb concluded that there was a lasting effect of infant experience on the problem-solving of the adult rat.

Beach and Jaynes[18] adopted Hebb's viewpoint to interpret previous findings concerning the effect of early experience on later behaviour. They argue for instance that such phenomena as hoarding, increased sucking behaviour and failure of dark-reared chicks to peck normally is due to sensory or perceptual deficiencies. The authors go on to present their

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[17] D.O. Hebb, "The Effects of Early Experience on Problem-Solving at Maturity", The American Psychologist, Vol. 2, 1947, p. 307.

[18] F.A. Beach and J. Jaynes, "Effects of Early Experience Upon the Behaviour of Animals", Psychological Bulletin, Vol. 5, 1954, p. 243.

view of Hebb's theory.[19] Basically, the theory predicts that animals that have had a large amount of perceptual experience early in life will prove better learners than others deprived of such experience. It is further predicted that the magnitude of this facilitative effect is, within limits, inversely related to the age at which the perceptual experience is gained. Visual perception in a spacious environment during early life facilitates adult learning ability, "What is learned is in terms of what is perceived; what is not perceived can hardly be remembered."[20]

The finding that animals reared in enriched environments appear to be better learners than animals reared in restricted environments has been repeatedly demonstrated on tests of shock avoidance, visual discrimination and open-field mazes. For example, Schweikert and Collins,[21] Clarke et al.[22] and Bingham and Griffiths[23] have found that enriched

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[19] Ibid., p. 255.

[20] D.O. Hebb, The Organization of Behavior, New York, Science Editions, 1961, p. 111.

[21] G.E. Schweikert and G. Collins, "The Effects of Differential Postweaning Environments on Later Behavior in the Rat", The Journal of Genetic Psychology, Vol. 109, 1966, p. 262.

[22] R.S. Clarke, W. Heron, M.L. Fetherstonhaugh, D.G. Forgays and D.O. Hebb, "Individual Differences in Dogs: Preliminary Report on the Effects of Early Experience", Canadian Journal of Psychology, Vol. 5, 1951, p. 156.

[23] W.E. Bingham and W.J. Griffiths, "The Effect of Differential Environments During Infancy on Adult Behaviour in the Rat", Journal of Comparative and Physiological Psychology, Vol. 45, 1952, p. 311.

animals made fewer errors and required fewer trials to meet a learning criterion; Reynolds[24] also notes similar results for companionship-reared animals as opposed to isolated animals. Thompson and Heron[25] attribute these and related group differences to early perceptual experience more than opportunity for motor activity.

In fact, Forgays and Forgays[26] have shown that rats which had been reared in small mesh cages, which did not limit their perception but reduced their opportunities for motor activity, made lower error scores on the Hebb-Williams closed-field test than did animals which had been reared in large cages, but whose perceptual experience had been limited. These authors have also found that enriched rats having playthings were better problem-solvers than restricted groups, those without playthings, although inferior to those raised with playthings, were better than the restricted groups. These results also indicate that the enriched rats use extrafield visual distance cues to a much greater extent in

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[24] H.H. Reynolds, "Effects of Rearing and Habituation in Social Isolation on Performance of an Escape Task", Journal of Comparative and Physiological Psychology, Vol. 56, 1963, p. 520.

[25] W.R. Thompson and W. Heron, "The Effects of Restricting Early Experience on the Problem-Solving Capacity of Dogs", Canadian Journal of Psychology, Vol. 8, 1964, p. 24.

[26] D.G. Forgays and J.W. Forgays, "The Nature of the Effect of Free-Environment Experience in the Rat", Journal of Comparative and Physiological Psychology, Vol. 45, 1952, p. 327-328.

maze situations than do restricted animals and hence the former attain faster learning scores.[27]

Forgays and Read[28] also discovered that the enrichment period immediately after weaning produced the best problem-solvers as compared with the same exposure during the first three weeks of life or at maturity. In this line, Hymovitch[29] states that if free environment experiences are to have a beneficial effect on the animals' maze-solving ability they must take place early in life. More specifically, a group which was in a free environment early in life and then later restricted was superior to a group which was restricted early and then later placed in a free environment. Secondly, a group raised in a free environment throughout was no different from one restricted later in life after having been in a free environment. And finally, a continually restricted group was no lower than one restricted only in early life.

The relationship between differential environment and problem-solving behaviour has been interpreted by some of the

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[27] R.T. Brown, "Early Experience and Problem-Solving Ability", Journal of Comparative and Physiological Psychology, Vol. 65, No. 3, 1968, p. 433.

[28] D.G. Forgays and J.M. Read, "Crucial Periods for Free-Environmental Experience in the Rat", Journal of Comparative and Physiological Psychology, Vol. 55, No. 5, 1962, p. 817.

[29] B. Hymovitch, "The Effects of Experimental Variations on Problem-Solving in the Rat", Journal of Comparative and Physiological Psychology, Vol. 45, 1952, p. 320.

preceding authors as representing a difference in "intelligence" or "shifting ability"[30] or ability to break a set[31] between the two groups. However, Zimbardo and Montgomery[32] and Woods *et al*.[33] argue that perhaps the differential environmental conditions are producing differences in amount of exploration and not in intelligence. The finding that restricted dogs explore significantly more than enriched dogs had been previously stated in the early work of Thompson and Heron.[34] This group of authors speculate within the theoretical framework of Dember and Earl's[35] analysis that perhaps the superiority in problem-solving ability for subjects with rich early experience may arise as a result of the relatively decreased

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30 A.S. Luchins and R.H. Forgus, "The Effect of Differential Post-Weaning Environments on the Rigidity of an Animal's Behavior", *Journal of Genetic Psychology*, Vol. 86, 1955, p. 57.

31 C.S. Hoffman, "Effect of Early Environmental Restriction on Subsequent Behavior in the Rat", *The Psychological Record*, Vol. 9, 1959, p. 176.

32 P.P.G. Zimbardo and K.C. Montgomery, "Effects of Free Environment Rearing Upon Exploratory Behavior", *Psychological Reports*, Vol. 3, 1957, p. 593-594.

33 P.J. Woods, S.I. Ruckelhaus and D.M. Bowling, "Some Effects of Free and Restricted Environmental Rearing Conditions Upon Adult Behavior in the Rat", *Psychological Reports*, Vol. 6, 1960, p. 191.

34 W.R. Thompson and W. Heron, "The Effects of Early Restriction on Activity in Dogs", *Journal of Comparative and Physiological Psychology*, Vol. 47, 1954, p. 82.

35 W.N. Dember and R.W. Earl, "Analysis of Exploratory, Manipulatory and Curiosity Behaviours", *Psychological Review*, Vol. 64, No. 2, 1957, p. 91-92.

novelty of the test situation for the free-environment subjects and thus reflect less exploratory behaviour, that is, a lower distractibility level from the task at hand. In a subsequent study, Woods et al.[36] found that two enriched and deprived groups under conditions of food deprivation made fewer errors in a maze task than two identical enriched and deprived groups not deprived of food. Cohen and Stettner[37] believe that amount of exploration is inversely related to drive level. Instead of the term exploration, Berlyne[38] perfers the term "perceptual curiosity" to explain the same phenomenon. Sackett[39] has also found that modest degrees of sensory deprivation appear to produce maximum interest in novel and in complex visual input immediately after removal

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[36] P.J. Woods, A.S. Fiske and S.I. Ruckelhaus, "The Effects of Drives Conflicting with Exploration on the Problem-Solving Behavior of Rats Reared in Free and Restricted Environments", Journal of Comparative and Physiological Psychology, Vol. 54, 1961, p. 168.

[37] J.S. Cohen and L.J. Stettner, "Effect of Deprivation Level on Exploratory Behavior in the Albino Rat", Journal of Comparative and Physiological Psychology, Vol. 66, No. 2, 1968, p. 514.

[38] D.E. Berlyne and J. Slater, "Perceptual Curiosity, Exploratory Behavior and Maze Learning", Journal of Comparative and Physiological Psychology, Vol. 50, No. 4, 1957, p. 228.

[39] G.P. Sackett, "Response to Stimulus Novelty and Complexity as a Function of Rats' Early Rearing Experiences", Journal of Comparative and Physiological Psychology, Vol. 63, No. 3, 1969, p. 374.

from the rearing environment. McCall[40] attributes such findings to the more rapid habituation to the strange environment by the more widely experienced subjects.

Based on the generally accepted notion that visual enrichment at an early age facilitates adult problem-solving and affects later exploratory behaviour, the writer also wishes to investigate whether auditory, tactile and olfactory stimulation have an additional effect on these behavioural variables in adult life.

4. Early Sensory Enrichment: Anatomical-Chemical Findings.

Based on Hebb's hypothesis, a group of workers--Krech, Rosenzweig, Bennett, Diamond, La Torre and others studied the effects of early environmental complexity on the brain of rats and other animals. The findings[41] concerning enriched animals include greater weight of the cerebral cortex and a greater cortical/subcortical weight ratio, the medial occipital region[42] showing the largest changes in

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[40] R.B. McCall, "Movable and Immovable Object Experience and Exploratory Behavior", <u>Psychonomic Science</u>, Vol. 8, 1967, p. 474.

[41] M.R. Rosenzweig, "Environmental Complexity, Cerebral Change, and Behavior", <u>American Psychologist</u>, Vol. 21, 1966, p. 321-322.

[42] M.C. Diamond, F. Law, H. Rhodes, B. Lindner, M.R. Rosenzweig, D. Krech and E.L. Bennett, "Increases in Cortical Depth and Glia Numbers in Rats Subjected to Enriched Environment", <u>Journal of Comparative Neurology</u>, Vol. 128, 1966, p. 125.

weight or depth and the somesthetic cortex, the least.

The greater weight of the cortex of enriched rats reflects greater thickness of the cortex (except the outermost layer), a thicker hippocampus, larger capillary diameter in the cortex, and more complex dendritic branching in neurons of the visual cortex.[43]

In addition, the total activity of acetylcholinesterase was found to increase slightly, but consistently in the enriched animals both in the cortex and the rest of the brain. In the cortex, this increase in enzymatic activity is less than the increase in tissue weight, so the activity per unit weight decreases in the enriched animals. This decrease suggests that the growth of cortex with use involves especially elements low in acetylcholinesterase such as glia, noncholinergic neurons and blood vessels and blood volume, whereas the increase in total cholinesterase activity in the cortex may be an indication of the growth of glia cells since these are relatively high in cholinesterase activity.[44,45]

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[43] M. R. Rosenzweig, A.L. Leiman, "Brain Functions", Annual Review of Psychology, Vol. 19, 1968, p. 64.

[44] E.L. Bennett, M.C. Diamond, D. Krech, M.R. Rosenzweig, "Chemical and Anatomical Plasticity of Brain", Science, Vol. 146, 1964, p. 616.

[45] M.R. Rosenzweig, D. Krech, E.L. Bennett and C. Diamond, "Effects of Early Environmental Complexity and Training on Brain Chemistry and Anatomy: A Replication and Extension", Journal of Comparative and Physiological Psychology, Vol. 55, 1962, p. 435.

However, Rosenzweig mentions that visual experience is not a necessary component of the conditions that induce changes in occipital and other cortical regions. Significant brain differences arise between littermates kept in enriched or impoverished environments even if the animals are blinded or are kept in total darkness. Other species of rodents, such as the mice and gerbil also show significant brain differences as a result of enriched or impoverished experience, but the occipital effect does not appear to predominate in these species as it does in the rat. On measures of brain weight and brain chemistry, the rat and gerbil, however, resemble each other more closely than either does the mouse.[46] The gerbil effects, while paralleling closely those found in the rat, are generally smaller in magnitude. La Torre[47] also reports similar findings with mice.

Altman _et al_.[48] have recently discovered that animals having had complex visual discrimination training, an enriched social environment and handling had longer cerebral hemispheres

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[46] M. R. Rosenzweig and E.L. Bennett, "Effects of Differential Environments on Brain Weights and Enzyme Activities in Gergils, Rats and Mice", unpublished paper, 1969.

[47] J.C. La Torre, "Effect of Differential Environmental Enrichment on Brain Weight and on Acetylcholinesterase and Cholinesterase Activities in Mice", _Experimental Neurology_, Vol. 22, 1968, p. 493.

[48] J. Altman, R.B. Wallace, W.J. Anderson and G.D. Pas, "Behaviorally Induced Changes in Length of Cerebrum in Rats", _Developmental Psychobiology_, Vol. 11, No. 2, 1968, p. 112.

than passive littermates reared in isolation and unhandled during infancy. A study by Essman[49] has also shown that isolated mice displayed higher levels of locomotor activity than group-housed mice as well as elevated brain serotonin levels.

Enriched groups[50] show lower cortical cholinesterase activity but higher subcortical activity than corresponding restricted groups, the enriched groups being lower than the restricted groups in cortical/subcortical ratio. The observed fall in cortical specific activity of cholinesterase (cholinesterase activity per unit of weight) in the enriched rats was due at least in part to the fact that the cortical weights were increasing at a faster rate than their total cholinesterase activity.

It was further found that a high cholinesterase level is associated with an ability to maintain a probabilistic response pattern in reversal discrimination problems, while a low cholinesterase level is associated with a more thorough commitment to the dominant stimulus. Krech believes that the

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[49] J.P. Essman, "Differences in Locomotor Activity and Brain Serotonin Metabolism in Differentially Housed Mice", Journal of Comparative and Physiological Psychology, Vol. 66, No. 1, 1968, p. 244.

[50] M.R. Rosenzweig, D. Krech, E.L. Bennett and C. Diamond, "Effects of Early Environmental Complexity and Training on Brain Chemistry and Anatomy: A Replication and Extension", Journal of Comparative and Physiological Psychology, Vol. 55, 1962, p. 435.

cholinesterase activity level provides a measure of the readiness of nerve impulse transmission in the CNS; the relative ease of nerve impulse transmission being correlated with capacity for more adaptive behaviour.[51] It appears, however, that the cerebral effects of an early period in an impoverished environment can be reversed in part, by a succeeding period in an enriched environment.[52]

The relevance of the present discussion in this study becomes more apparent when one considers the possible link between enzymatic activity and PEPs.

If differential environments affect the cholinesterase activity of the brain and if, as Szerb[53] suggests, the later components of the evoked potential reflect the activity of cholinergic synapses, then differential rearing may produce differences in the PEP waveform of enriched and impoverished animals.

However, the observed relationship between differential rearing, enzymatic activity and adaptive behaviour as

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[51] D. Krech, M.R. Rosenzweig and E.L. Bennett, "Dimensions of Discrimination and Level of Cholinesterase Activity in the Cerebral Cortex of the Rat", Journal of Comparative and Physiological Psychology, Vol. 49, 1956, p. 268.

[52] M.R. Rosenzweig, D. Krech, E.L. Bennett, J.F. Zolman, "Variation in Environmental Complexity and Brain Measures", Journal of Comparative and Physiological Psychology, Vol. 55, 1962, p. 1092.

[53] J.C. Szerb, "Averaged Evoked Potentials and Cholinergic Synapses in the Somatosensory Cortex of the Cat", EEG and Clinical Neurophysiology, Vol. 18, 1965, p. 140-146.

reported by Rosenzweig and the California group has recently been subjected to a number of criticisms.

Karczmar,[54] for instance, points out that the impoverished rats were behaviourally inferior to the enriched rats only in certain experimental conditions, and mentions that the terms "rich" and "poor" environment bear connotations unacceptable to many. From the biochemical and pharmacological viewpoint, Karczmar questions the significance of the differences obtained which, in some cases, are of the order of three per cent. Furthermore, the accuracy of the bioassay technique used for the measurement of acetylcholinesterase is also questioned. Finally, the author doubts the validity of the extrapolation from cholinesterase and acetylcholinesterase levels to behaviour. In fact, Karczmar reports differences of up to four hundred per cent in brain acetylcholinesterase, cholinesterase and serotonin levels without any resulting differences in learning or exploratory behaviour.

Russel[55] further suggests that even if the precision of measurement of acetylcholinesterase and cholinesterase were valid, one cannot conclude that a particular neurochemical

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[54] A.G. Karczmar, "Is the Central Cholinergic Nervous System Overexploited?", Federation Proceedings, American Society for Pharmacology and Experimental Therapeutics Symposium on Central Cholinergic Transmission and Its Behavioral Aspects, Vol. 28, No. 1, 1969, p. 155-156.

[55] R.W. Russel, "Behavioral Aspects of Cholinergic Transmission", Federation Proceedings, American Society for Pharmacology and Experimental Therapeutics Symposium on Central Cholinergic Transmission and Its Behavioral Aspects, Vol. 28, No. 1, 1969, p. 122-123.

variable is uniquely related to a behavioural variable until it is established that other neurochemical variables are not related to the behavioural variable. The author also questions the validity and reliability of the behavioural tests employed.

In answer to some of the preceding criticisms, Bennett and Rosenzweig[56] state that the differences induced in the brain by differential experiences are not large, but are nevertheless consistent and reproducible. Concerning the accuracy of the acetylcholinesterase activity analysis, the California group analyzes each tissue sample in duplicate, the two analyses not varying by more than two per cent. Furthermore, since each experimental group consists of at least ten animals, a further reduction of error is thus achieved. In addition, the values reported are usually based on a number of successive experiments showing similar effects. A number of successful replications of the original findings further lend support to the California investigations, despite the above-mentioned criticisms.

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[56] E.L. Bennett and M.R. Rosenzweig, "Comments and General Discussion", Federation Proceedings, American Society for Pharmacology and Experimental Therapeutics Symposium on Central Cholinergic Transmission and Its Behavioral Aspects, Vol. 28, No. 1, 1969, p. 158.

5. Early Sensory Restriction: Theory and Experimental Evidence.

In the area of early sensory deprivation, Ronald Melzack's work deserves particular mention since it has generated a voluminous amount of experimentation and related theorizing to account for the behavioural data.

Melzack raised dogs from infancy to maturity in lighted cages that restricted their visual experience but did not deprive them of all patterned stimulation. After release, they had greater difficulties than normally raised littermates in performing a simple black-white discrimination and in subsequent reversal training.[57] Melzack interprets the differences to heightened excitement and arousal on the part of the restricted dogs which interferes with discrimination and the selection of relevant cues from the environment. Restricted dogs also require more shocks before they learn to make the proper avoidance responses.[58]

Melzack[59] has also found that a new environment presented to restricted animals brings excited activity, failure

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[57] R. Melzack, "Effects of Early Perceptual Restriction on Simple Visual Discrimination", Science, Vol. 137, 1962, p. 978-979.

[58] R. Melzack and T.H. Scott, "The Effects of Early Experience on the Response to Pain", Journal of Comparative and Physiological Psychology, Vol. 50, 1957, p. 160.

[59] R. Melzack, "Effects of Early Experience on Behaviour: Experimental and Conceptual Considerations", in Hoch and Zubin (eds.), Disorders of Perception, New York, Grune and Stratton, 1965, p. 273-274.

to attend selectively to environmental stimuli (i.e. more prolonged random exploration) as compared to control dogs. Restricted dogs show little response to noxious stimulation such as nose-burning and pin-pricking. They manifest greater difficulties in delayed response and other cognitive tests such as mazes. They also are submissive to normally reared dogs and exhibit excessive licking behaviour. They also fail to discriminate sexually relevant cues, pay little attention to sounds and fail to inhibit irrelevant response patterns (i.e. extinction and non-reinforcement).[60] Melzack and Thompson[61] also showed that, compared to control dogs, restricted dogs continued to show much diffuse excitement but little socially organized curiosity over successive days to other dogs behind a wire mesh. The same was true for socialization with a friendly man.

Melzack's interpretation reflects a two-part process in which filtering processes are proposed as possible interpretation for the findings:

> There is inadequate filtering of inputs on the basis of memory (phase sequences) of the significance of stimuli normally acquired in early experience so that the total input bombarding the central nervous system produces an excessive CNS arousal, which, as Hebb has suggested, could be responsible for the correspondingly low cue properties necessary for discrimination and adaptive response.[62]

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[60] Ibid., p. 273-274.

[61] R. Melzack and W.R. Thompson, "Effects of Early Experience on Social Behavior", Canadian Journal of Psychology, Vol. 10, 1956, p. 85-88.

[62] Melzack, "Effects of Early Experience on Behaviour: Experimental and Conceptual Considerations", p. 276.

According to Melzack[63] two kinds of fibers are activated upon stimulation: the fast-conducting and the slow-conducting. He assumes that the inputs arriving at the cortex via the fastest conducting fibers that traverse the dorsal column and lemniscal fibers to thalamic and cortical areas activate "phase sequences" corresponding to earlier experience which can then exert dynamic information selection control (via centrifugal fibers) at lower synaptic levels of the more slowly conducting fibers that carry information on a number of stimulus properties. The past experience would be able to influence the selection of particular patterns to subserve perception and response while other patterns are inhibited or otherwise filtered out. In the absence of prior experience then, all stimuli in a totally new environment would be equally meaningful or meaningless, no association could provide a basis for selective attention to one stimulus more than another. Therefore Melzack believes that because of inadequate filtering at the early stages of information processing, both relevant and irrelevant inputs bombard the neural systems producing sensory and affective arousal which interferes with mechanisms that act in the selection of cues for adaptive response.

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63 *Ibid.*, p. 278.

Physiologically, the high arousal should be accompanied by a reduction of afferent signals during the transmission process. Moreover, since attentional processes play an important role in determining the amplitudes of evoked responses, the characteristic fluctuations in attention indicated by the behaviour of the restricted dogs should be reflected by continous changes in the amplitude and waveform of the evoked responses. Further experiments with dogs by Melzack and Burns[64] and with cats by Horn[65] show that the EEG and EP respectively of restricted animals display lowered amplitudes when the animals are permitted to look at a novel environment through their open cage doors; the responses evoked in the reticular formation and cortex by clicks and light flashes are reduced in amplitude and may be altered in wave form, during the presentation of the novel environment. This indicates the long time-course required for restricted animals to gain "familiarity" with a novel environment. Horn concludes that attenuation of evoked responses might serve to improve sensory contrast between signal and background.

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[64] R. Melzack and S.K. Burns, "Neurophysiological Effects of Early Sensory Restriction", Experimental Neurology, Vol. 13, 1965, p. 171.

[65] G. Horn, "Electrical Activity of the Cerebral Cortex of the Unanaesthetized Cat During Attentive Behaviour", Brain, Vol. 83, 1960, p. 57-76.

Fuller[66] has also suggested that isolated animals do poorly on problem-solving tasks because of increased CNS arousal and that isolated animals become habituated to a very low level of stimulation and respond to average stimulation as normally reared animals respond to violent stimulation. He attributes this phenomenon to the shock of emergence in a strange world. One role of early experience is that of allowing the organism to become habituated to multitudinous stimuli so that it can direct its responses to one or a few which are significant.[67]

Along this line of thought, R. Hernandez-Peon *et al*.[68] found that when an animal's attention was attracted by non-visual stimuli, *PEP*s recorded in the visual cortex, lateral geniculate body and optic tract were reduced in amplitude. It was concluded that if during attentive behaviour, sensory inhibition occurs in all other sensory paths, except the ones concerned with the object of attention, such an inhibitory mechanism might lead to the favouring of the attended object by the selective exclusion of incoming signals. Removal or

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[66] J.L. Fuller, "Experiential Deprivation and Later Behavior", *Science*, Vol. 158, No. 3807, 1967, p. 1645.

[67] *Ibid*., p. 1650.

[68] R. Hernandez-Peon, C. Guzman-Flores, M. Alcaraz and A. Fernandez-Guardiola, "Photic Potentials in the Visual Pathway During 'Attention' and Photic 'Habituation'", *Federation Proceedings of the American Physiological Society*, Vol. 15, 1956, p. 91-92.

loss of plastic inhibition in the polysensory system will bring about a state of diffuse central hyperexcitability in which a single afferent volley will discharge a great number of neurons throughout the brain. In a subsequent article, Hernandez-Peon goes on to say:

> From teleological reasoning, centrifugal inhibition of non-significant sensory signals at their entrance to the CNS is a useful mechanism for the individual. It is likely that the regulation of that mechanism is altered in some pathological states. For instance, failure of afferent neuronal habituation, resulting in excessive entrance of sensory signals to the brain, would explain the unusual responsiveness of neurotic patients and their heightened perception of non-significant stimuli.[69]

With reference to Lindsley's activation theory, Malmo[70] states that the continuum extending from deep sleep at the low activation and to excited states at the high activation end is very largely a function of cortical bombardment by the ARAS, such that the greater the cortical bombardment, the higher the activation. The relation between activation and behavioural efficiency is described by an inverted U curve. That is, from the activation at a low level up to a point that is optimal for a given function,

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[69] R. Hernandez-Peon, "Neurophysiological Correlates of Habituation and Other Manifestations of Plastic Inhibition", EEG and Clinical Neurophysiology, Suppl. 13 (part 8), 1960, p. 106.

[70] R.B. Malmo, "Activation: A Neuropsychological Dimension", Psychological Review, Vol. 66, No. 6, 1959, p. 367-386.

level of performance rises monotonically with increasing activation level, but beyond this optimal point the relation becomes non-monotonic: further increase in activation beyond this point produces a fall in performance level, this fall being directly related to the amount of the increase in level of activation. Again, according to Malmo's view, when appropriate stimulation occurs, the previously latent effect of deprivation will show itself in the heart rate, within limits, the longer the period of deprivation, the higher the heart rate. Furthermore, according to activation theory, the same central mechanism (ARAS) that increases heart rate also acts to increase bombardment of the cerebral cortex. Hahn[71] has also found that the heart rate of the rat increases as drive state or arousal increases under prolonged food deprivation: the absence of differences in heart rate between subjects pressing a 15 gram pressure bar and a 60 gram pressure bar indicates that physical activity has little effect on heart rate. Hein[72] however has noted that in the rat and the monkey one finds acceleration of heart rate to shock whereas one obtains deceleration to shock in the cat. The author

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[71] W.W. Hahn, J.A. Stern, F.S. Fehr, "Generalizability of Heart Rate as a Measure of Drive State", Journal of Comparative and Physiological Psychology, Vol. 58, No. 2, 1964, p. 305.

[72] P.L. Hein, "Heart Rate Conditioning in the Cat and Its Relationship to Other Physiological Responses", Psychophysiology, Vol. 5, 1969, p. 455.

concludes that heart rate change varies both among the species of animal used and within the species as well.

Consequently, apart from the behavioural manifestations resulting from deprivation one could speculate in the light of the theoretical viewpoints presented above, that sensory enrichment and deprivation produce differential arousal and activity levels, as defined by PEP amplitude, heart rate and activity measures.

6. Early Differential Environments and Emotionality.

In the light of his general theoretical framework, Melzack[73] states that novel sensory inputs or inputs incongruous with past experience are equated with perturbation and disequilibrium. In general, emotion involves orienting behaviour, arousal or activation as well as cognitive processes in the form of memory against which the input is matched, and which provides the direction and course of emotional experience and response.

The work of Denenberg *et al.*[74] has shown that rats reared in a free environment after weaning engage in more

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[73] R. Melzack, "Brain Mechanisms and Emotion", in D.C. Glass (ed.), *Neurophysiology and Emotion*, New York, Rockefeller University Press, 1967, p. 60-69.

[74] V.H. Denenberg, G.G. Karas, K.M. Rosenberg and S.F. Schell, "Programming Life Histories: An Experimental Design and Initial Results", *Developmental Psychobiology*, Vol. 1, No. 1, 1968, p. 4.

complex social interactions and are less emotional in the open-field test than are cage-housed rats. Menzel et al.[75] compared two groups of young chimpanzees captured in the field and four groups reared from birth in small cubicles for a two-year period. When observed for two hours alone in an unfamiliar room, the isolated animals performed stereotypies such as swaying and thumbsucking, extreme fright and withdrawal behaviour. They also manifested little overt activity and were more often in the prone or supine position than the wild-born animals. Mason and Green[76] compared the reactions of feral and socially deprived lab-reared monkeys to albino rats and found that the restricted monkeys exhibited clasping, crouching, stereotypied movements and excessive sucking behaviour. Feral animals made more social contacts with the rat in the living cage, were gentler with it and selected it more frequently in subsequent tests in which it appeared as a social incentive. The authors also mention that the syndrome of self-directed responses shown by the socially restricted monkeys is similar to that seen in lab-reared chimpanzees, in autistic children, in mental

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[75] E.W. Menzel, R.K. Davenport and C.M. Rogers, "Effects of Environmental Restriction Upon the Chimpanzee's Responsiveness in Novel Situations", Journal of Comparative and Physiological Psychology, Vol. 56, No. 2, 1963, p. 329-333.

[76] W.A. Mason and P.C. Green, "The Effects of Social Restriction on the Behavior of Rhesus Monkeys: IV Responses to a Novel Environment and to an Alien Species", Journal of Comparative and Physiological Psychology, Vol. 55, No. 3, 1962, p. 366-367.

defectives and in institutionalized children with no prior history of psychiatric or organic disorder.

7. Early Differential Environments and Evoked Potentials.

The work of Risen[77] has demonstrated that rabbits deprived of all light from birth display simplified and long-latency cortical EPs when compared with normal animals at four to twelve months of age. They resemble, in this respect, newborn animals and animals shortly after the opening of their eyes. The amplitude of late responses measured away from the primary projection area is typically very large initially; however, with exposure to normal illumination, there is a gradual shortening in the latency of the primary response at the visual cortex and a growth in the amplitude of this and succeeding deflections. It is also interesting to note that Bradley *et al*.[78] found that the latency between the stimulus and the beginning of the negative wave and the duration of the negative wave of the EP were both longer in the cretinous rats than in the normal rats, whereas the

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[77] A.H. Risen, "Sensory Deprivation", in Stellar *et al*. (eds.), *Progress in Physiological Psychology*, Vol. 1, New York, Academic Press, 1966, p. 133-134.

[78] P.B. Bradley, J.T. Eayrs and N.M. Richards, "Factors Influencing Potentials in Normal and Cretinous Rats, *EEG and Clinical Neurophysiology*, Vol. 17, 1964, p. 312.

amplitude of the EP response of the cretinous rats was significantly less than in the normal.

At this point, the author would like to consider three particular studies which seem more directly relevant to the present investigation.

In a social and sensory isolation study with pups, Fox[79] found that after one week of isolation between the fourth and fifth week of age, the isolated group (no visual contact with littermates and personnel) differed significantly from the control group (visual contact with other animals and personnel) in many respects.

The EEG of the isolated group showed hyperactive activity upon emergence from isolation (marked desynchronization low amplitude activity) suggesting a highly aroused state due to increased sensitivity to stimuli following the sensory isolation. Also noted were aimless nonspecific exploration and a greater interest with inanimate objects than with the experimenter. In addition, Fox reports abnormally short latencies of PEPs on the part of the isolates at five weeks, whereas one week later, this phenomenon had disappeared. Fox interprets his findings in terms of maximal reactivity to the novel situation on the part of the isolates and believes that

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[79] M.W. Fox, "The Effects of Short-Term Social and Sensory Isolation Upon Behavior, EEG and Averaged Evoked Potentials in Puppies", Physiology and Behavior, Vol. 2, 1967, p. 145-149.

such animals are reacting without their afferent filtering systems operating, that is, with minimal internal inhibition. Fox points out that EEG studies of autistic children show almost identical behaviour patterns to isolation-reared animals and that the EEG manifestations of constant desynchronization suggest a state of chronic reticular arousal.

The work recently carried out at the University of Ottawa suggests a relationship between behavioural efficiency and various latency measures of the PEP waveform. In a preliminary study, Edwards *et al.*,[80] using sixteen male Sprague-Dawley albino rats, compared the mean latencies of enriched and impoverished subjects on each of three occasions. Two weeks after the establishment of the differential environments, the mean PEP latency of the event of greatest amplitude and between 25 and 75 msec, for the enriched group was 37.2 msec as compared with 46.4 msec for the impoverished group, the difference being significant at the .01 level. Four and six weeks later the differences between the latencies of the groups remained in the same direction and were significant at the .0001 and .001 level of probability, respectively. The results suggested differences in brain functioning efficiency brought about by the differential rearing conditions.

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[80] H.P. Edwards, W.F. Barry and J.O. Wyspianski, "Early Environment Effects on Rat Photic Evoked Potentials: A Preliminary Study", Revista Interamericana de Psicologia, Vol. 2, No. 2, 1968, p. 88-89.

A later publication consisting of two separate experiments divided Sprague-Dawley albino rats into enriched and impoverished groups at twenty-one days of age, using the split-litter technique. The enriched subjects were reared in a large wire mesh cage containing black and white toys, whereas the impoverished subjects were housed in single small wire mesh cages. In the first experiment,[81] the mean latencies of the groups were compared using "t" tests. Latencies for the negative peak studied in both groups were identical at twenty-one days of age (44 msec.). However, after eight weeks of differential rearing, the mean latency of the enriched group was 56 msec. and that of the impoverished group was 64 msec. (t: 3.90, $p < .01$). The animals were also administered a black-white Thompson discrimination test at the conclusion of the experimental period, the criterion performance being eight out of ten correct trials. The performance of the enriched group on this task was significantly superior to that of the impoverished group (Rank Test, $p < .05$).

In a second experiment albino rats were again subjected to the same rearing procedure as followed to the age of three months, with the exception that all enriched subjects

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[81] H.P. Edwards, W.F. Barry and J.O. Wyspianski, "Effect of Differential Rearing on Photic Evoked Potentials and Brightness Discrimination in the Albino Rat", Developmental Psychobiology, Vol. 2, No. 3, 1969, p. 134.

were placed in a multiple T-maze and allowed to explore it for a few minutes each day. Three EPs were taken of all subjects at monthly intervals. The events 1, 2, 3 were identified in the individual records; test-retest reliability of each event was obtained by comparing the latencies obtained from the first fifty as opposed to the second fifty stimuli. To check latency differences, "t" tests and non-parametric rank tests were used. The following results were obtained.[82] At twenty-one days of age, there were no significant differences in mean latencies of both groups for the three events considered. After four weeks of differential rearing, however, the impoverished group had longer latencies in all three events and the latency difference between enriched and impoverished subjects was significant with respect to event 3 at the .05 level. After eight weeks of differential rearing, event 3 was no longer significantly different, but event 1 showed a significant difference between the groups, again at the .05 level, the impoverished group having the longer latency. After nine weeks of differential rearing the enriched group appeared significantly superior (.05 level) on a discrimination task.

The present study thus attempts to replicate and extend these findings to the Mongolian gerbil and also wishes

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[82] Ibid., p. 137.

to investigate the possible effects of additional auditory, tactile and olfactory enrichment on the PEP and learning ability.

8. The Mongolian Gerbil in Behavioural Research.

The Mongolian gerbil[83] (Meriones unguiculatus) is a small desert rodent having pigmented eyes and resembling the kangaroo rat in general appearance. The gerbil weighs approximately 15 to 20 grams at its weaning age of three weeks and averages 80 to 90 grams at maturity. It is quite tame, does not bite and is easily maintained under laboratory conditions suited to the rat. Gerbils possess a high level of heat tolerance and show an unusual capacity for temperature regulation. Members of this genus dig elaborate underground holes, often at two levels, including numerous chambers being interconnected with a labyrinth of runways.

Walters *et al*.[84] report that in the Skinner box the gerbils excelled the rats throughout the experiment. For instance, seven of the nine gerbils avoided shock at least 97 per cent of the time on the fourth day, whereas none of the ten rats avoided even 80 per cent of the time on the same day.

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[83] G.C. Walters, J. Pearl and J.V. Rogers, "The Gerbil as a Subject in Behavioral Research", *Psychological Reports*, Vol. 12, 1963, p. 315.

[84] *Ibid*., p. 317.

It has been noted by Nauman[85] that gerbils demonstrated more frequent central area occupancy, greater duration of central area occupancy and greater locomotion in the field than albino rats. Campbell _et al_.[86] remark that the gerbil appears to engage in considerably more exploratory behaviour than is normally found in pigeon or rat. Reactivity to shock and avoidance responding in a two-way shuttlebox were compared in three species of rodents: gerbils, kangaroo rats and lab mice.[87] The gerbils though inferior to the mice avoided shocks at a markedly higher level than the kangaroo rats. The authors remark that the gerbils tend to be much more active in their cages, suggesting that shuttling for them may be a more "natural" response.

9. Summary and Hypotheses.

As previously mentioned, a number of investigators have reported a negative correlation between _PEP_ latencies and behavioural intellectual efficiency both in human and

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[85] D.J. Nauman, "Open Field Behavior of the Mongolian Gerbil", _Psychonomic Science_, Vol. 10, 1968, p. 163.

[86] N. Campbell, D. Straney and A. Neuringer, "Operant Conditioning in the Mongolian Gerbil", _Psychonomic Science_, Vol. 16, 1969, p. 256.

[87] R. Boice, C. Boice and A.E. Dunham, "Role of Docility in Avoidance: Gerbils and Kangaroo Rats in a Shuttlebox", _Psychonomic Science_, Vol. 10, 1968, p. 381-382.

animal subjects. Various authors have also found a negative correlation between PEP and EEG amplitude and arousal level, although this is by no means firmly established in the case of PEPs. According to one major theoretical viewpoint, the higher the arousal level or cortical bombardment of the CNS, the lower the EEG and PEP amplitudes when looking at a novel environment. If one adopts this viewpoint, the more aroused restricted animals with supposedly inadequate filtering systems should display lower EEG and PEP amplitudes than their enriched littermates. According to another theorist and experimenter, however, the lack of sensory selectivity or "plastic inhibition" on the part of restricted animals appears to be reflected in heightened PEP amplitude.

The first major hypothesis expressed in its null form thus reads:

> There are no significant differences in the PEP waveforms (latencies and amplitude) of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched and Deprived environments.

In the area of sensory stimulation and deprivation, a great number of studies have reported the superior learning capacity of animals with the greater infant experience or sensory-perceptual enrichment usually defined in terms of the visual cues provided.

This notion has been reinforced by the more recent anatomical and chemical evidence concerning enriched animals as well as the PEP findings with cretinous rats. In this context, the author also wishes to investigate the possible additional enrichment effects of auditory, tactile and olfactory stimulation on later adult behaviour and psychophysiological measures. The term Fully Enriched used by the author throughout the present research report thus refers to this group of animals.

Ronald Melzack attributes the inferior problem-solving capacity of the impoverished animals to heightened excitement and CNS arousal which interferes with the adequate filtering and selection of environmental inputs, since little or no significance of these stimuli has been acquired at an early age.

In view of such findings, the second major hypothesis expressed in its null form reads:

> There are no significant differences in the learning ability of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched and Deprived environments.

An alternative possibility has been suggested to account for the inferior problem-solving capacity of deprived animals. It has been proposed by a group of authors that differential environmental conditions produce differences in amount of exploration and not in intelligence. Experimental evidence indicates that restricted animals explore significantly more than enriched animals, thus paying little attention to the relevant cues and therefore obtaining higher error scores than enriched animals on most learning tasks. The author feels that such a contention appears logically sound and warrants investigation in this study.

In its null form, the first minor hypothesis thus reads:

> There are no significant differences in the amount of exploration of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched and Deprived environments.

The literature further suggests that environmentally deprived animals display a greater degree of emotional behaviour than control littermates.

The second minor hypothesis in its null form thus reads:

> There are no significant differences in the degree of emotionality of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched and Deprived environments.

Finally, a limited number of studies have reported that the longer the period of deprivation (usually defined in terms of food and water deprivation), the higher the activity level and heart rate of the animal. Two hypotheses will attempt to verify whether this general statement can be applied to the broader area of perceptual deprivation and enrichment.

The third and fourth minor hypotheses in their null form thus read:

> There are no significant differences in the activity levels of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched and Deprived environments.
>
> There are no significant differences in the heart rate levels of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched and Deprived environments.

Chapters II and III discuss the design, tools, methods and results of the present study.

CHAPTER II

EXPERIMENTAL DESIGN

This chapter presents in detail the experimental design used to test the working hypotheses presented in the previous chapter. The first and second sections describe the sample and apparatus used. The third and fourth sections specify the procedure and statistics used in the experiment.

1. The Sample.

As previously mentioned, studies on lower animals and more specifically on the albino rat have yielded results of theoretical and practical importance in the area of sensory stimulation and deprivation and later intellectual efficiency, both behaviourally and physiologically.

The Mongolian gerbil was chosen because of its docile behaviour, cleanliness, low disease susceptibility and easy maintenance under laboratory conditions suited to the rat. In addition, the growing literature on the rise of this species in animal research is almost unanimous in reporting the very rapid learning ability of the gerbil as compared to the rat.

In an attempt to replicate and extend such findings with another species, the final sample consisted of fifteen male Mongolian gerbils belonging to five litters born within a forty-eight hour period. The animals were received shortly after weaning at approximately twenty-five days of age.[1]

2. The Tools.

In this section, the tools used in obtaining <u>PEP</u> responses will first be described and illustrated. A presentation of the apparatus employed for the learning task, exploratory behaviour, activity test, heart rate and emotionality will follow.

For the recording of <u>PEP</u> waveforms, all animals were restrained in a gerbil restrainer designed by the experimenter and constructed by an Ottawa firm. This small restrainer consisted of a plastic base, a circular neck piece secured into the base by four alligator clips, and a small adjustable leather belt fitting around the animal's body. The tail and legs of the gerbil were immobilized with adhesive tape. Grass E1B Silver Needle electrodes were then inserted into the scalp and the leads connected to a Mousseau Amplifier model SA-3, Serial Number 014, which contained a filter with an attenuation slope of 6 db per octave roll-off, and set at a gain of 60,000.

The amplifier output was in turn connected to the input of Channel 1 (<u>EEG</u>) of a Thermionic Four-channel FM tape

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[1] The gerbils were obtained from the Burr Ridge animal farm in Hinsdale, Illinois.

recorder Model TDR3 set at a speed of 1-7/8, the gain controls of which were kept constant. Ampex magnetic tape was used for data storage. The output of Channel 1 went to the active Krohn-Hite Multi-Function Variable Filter Model 335 set at 0 db and adjusted to filter between 3 and 50 Hz. The continuous EEG was monitored on a Telequipment Oscilloscope Type D54 whereas the time-locked brain activity was displayed on a Fairchild Oscilloscope Model 708A.

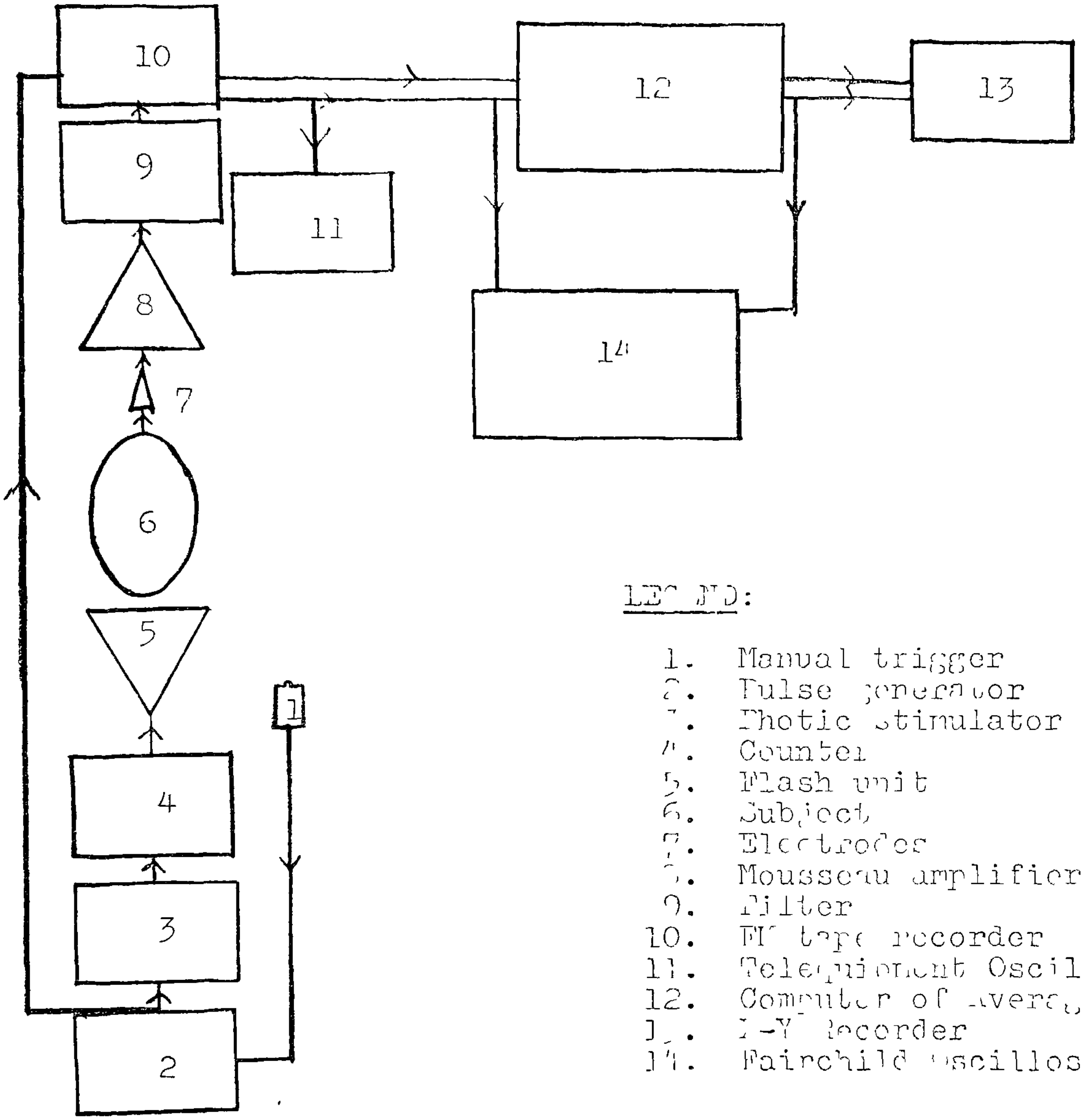
To obtain the PEP, photic stimuli were given using a Grass PS2 photo stimulator set at an intensity of 8 and triggered manually with a Rutherford Model B 14-R pulse generator and connected to Channel 3 of the tape recorder. The data were averaged on a Nuclear Data 1024 Enhancetron computer of average transients, set to sweep for 500 milliseconds following each stimulus, the computer input being set at 1 volt maximum and the display scale at 2. A TMC Scaler Model 150 counted the number of stimuli administered. The PEP waveform was then displayed on a Moseley 7035A X-Y Recorder.

Electrode Impedance was checked by means of an Applicon Impedance Meter Model GK. A Lafayette Four-track Solid State tape recorder Model 810 was used to record the squealing of the animal while in the restrainer. Heart rate was monitored on a small portable Nihon Kohden Cardiofax electrocardiograph Pat. 534907 set at 1 volt and using a half-second time base.

An illustration of the PEP equipment is presented in Figure 1. The next section describes the apparatus employed for the behaviour tests which including learning, exploration and activity tasks.

The learning test was conducted in a fully automatic Lafayette Shuttle Box consisting of two small metal compartments separated by a door. The apparatus contains a metal grid floor capable of delivering an electrical shock (Unconditioned Stimulus - US) of various intensity and duration, but only to the compartment which the animal occupies. The Conditioned Stimulus (CS) consists of a buzzer tone, the duration of which can also be preset according to the desire of the experimenter; at the onset of the tone the door separating the compartments is raised. The apparatus is also equipped with a shock delay unit which controls the time interval between the CS and US. The door closes automatically when the CS and/or US is terminated. The time interval between trials can also be preset to a specified point.

The basic idea for this learning task is to cross to the unshocked compartment before actually receiving a shock. The animal must learn to associate the onset of the sound with pain avoidance and immediately go to the other side of the unit, in which case this response is termed an "avoidance"



LEGEND:

1. Manual trigger
2. Pulse generator
3. Photic stimulator
4. Counter
5. Flash unit
6. Subject
7. Electrodes
8. Mousseau amplifier
9. Filter
10. FM tape recorder
11. Telequipment Oscilloscope
12. Computer of Average Transients
13. X-Y Recorder
14. Fairchild Oscilloscope

Figure 1. - Systems Diagram for the Recording of Photic Evoked Potentials on the Gerbil.

response. In the initial trials, of course, the animal has not learned this behaviour and consequently receives a certain number of shocks before rushing to the other compartment. This type of response is appropriately called an "escape response". The machine automatically types out whether the animal has performed an escape or an avoidance response as well as the time taken to cross from one compartment to the other.

The apparatus was set up as following: CS (buzzer): 7 sec; shock delay: 4 sec; US (shock): 3 sec; door delay: 7 sec; intertrial interval: 18-22 sec; shock intensity: .5 milliamperes.

The exploratory behaviour of the animals was observed in an exploration box specially designed and constructed by the experimenter. It consisted of a wooden box 44 inches in length, 18 inches in width, and 5 inches in height. The floor was brown in colour, whereas the walls were painted in alternating black and white vertical stripes approximately three inches in width. The box was divided into eight compartments of equal size arranged four in length and two in width, each compartment containing two openings 2 inches wide and 3 inches high. The unit was covered by a removable transparent screen raised approximately 1-1/2 inches above the partitions.

The assessment of the animals' activity level was done by means of a Lafayette metal activity cage, Model A 501. The cage dimensions were one foot in length, one foot in width and one foot in height and the unit was completed by a tightly fitting clear plastic covering. The floor unit of the cage which picked up the animal's movements was in turn connected to an A501 Activity Platform set at the maximum sensitivity level of 10. A Cumulative Recorder Model CR2D made by the Scientific Prototype Manufacturing Corporation recorded on paper the amount of activity for each animal. The 28-volt power for this stepper device was supplied by a Scientific Prototype Skinner Box Model A 106.

3. The Experiment.

The experiment consisted of splitting an initial sample of seven litters of twenty-five-day-old male Mongolian gerbils into three groups labelled "Fully Enriched", "Visually Enriched" and "Deprived" groups. Random assignment to each of the groups was performed by the split-litter technique whereby one animal from each litter was identified by a code symbol painted on the tail and assigned to each of the environmental conditions. Physiological and behavioural measures were taken after two months of differential rearing.

The seven Fully Enriched animals were housed in a gray metal cage measuring 48 inches by 30 inches by 20 inches, the front, top and bottom sections of which consisted of wire mesh. This group was provided with the following playthings: an activity wheel, several tunnels, a sand box containing various forms of cactus plants during the first few days and a number of toys such as small cars, trucks, boats, dolls, wooden obstacles and plastic animals. The walls were covered with painted geometric patterns of various sizes and colours; circular objects and more coloured patterns hung from the top of the cage. The floor provided additional tactile experience, being covered with carpet, sandpaper, newspaper, "paper-mâché" and various types of cloth. Auditory enrichment was performed by means of rattles and other toys emitting sounds when the animal stepped on them. A small portable radio was turned on for a two- to three-hour period six days a week. Olfactory stimulation was provided daily by means of various non-harmful commercial liquids and sprays.

The Visually Enriched group was housed in a cage of identical dimensions as the above and received, as far as possible, the same stimulation, except for the concentrated auditory, olfactory and tactile experience.

The Deprived animals were placed in small isolated metal cages measuring 9 inches by 8 inches by 7 inches, the front and bottom portions consisting of wire mesh. The cages were so situated as to permit adequate light and air while, however, providing as little opportunity as possible for patterned stimulation except during brief weekly cage cleaning periods.

A constant supply of Laboratory Cubes was provided for all subjects throughout the experiment, based on a self-feeding schedule. It was noted that the initial lighter diet of grain and sunflower seeds did not seem to provide adequate teeth and gum stimulation since the animals from all three groups chewed either their playthings or the wire mesh rather consistently. This mixture was removed after the first week of differential rearing.

It may be noted that the playthings and geometric patterns placed weekly into the Fully Enriched environment were transferred to the Visually Enriched cage for the next week and vice versa so as to provide, as much as possible, the same visual stimulation to animals of both groups.

Because of the additional auditory and olfactory enrichment received by the Fully Enriched animals, it became necessary to house this group in one room and the two other groups in a second room of comparable size. Temperature in both laboratories was kept between 75 and 80 degrees Farenheit, in accordance with the supplier's recommendations. At the end of the first half of the experiment, the possible contaminating effect of the two rooms was counterbalanced by transferring the group housed in the first lab to the second, and vice versa. All animals were kept, as closely as possible, on a twelve-hour light-dark schedule. Animal handling was kept to a minimum so as to eliminate this possible confounding effect on the final results. It is believed that the environmental design and procedure approximated that described by most authors in their sensory enrichment and deprivation studies, with the exception, of course, of the Fully Enriched group.

The writer wishes to note that of the initial twenty-one experimental animals, only two died, the first shortly after the establishment of differential rearing and the second (a deprived animal) while being immobilized for purposes of PEP recording. The death of the first was attributed to abnormally inferior weight upon delivery from the supplier and subsequent failure to eat, the death of the second being due to an abrupt movement of the experimenter with the neck piece of the restraining device. Six animals were thus eliminated from the study leaving a final sample of fifteen gerbils, all seemingly in excellent health; the mean weight of the animals in each group being very similar both at the beginning and at the end of the experiment.

The writer now wishes to outline the procedure employed in obtaining the physiological and behavioural data by means of which the working hypotheses stated in Chapter I are tested.

All subjects were placed in individual cages measuring 9 inches by 8 inches by 7 inches twenty-four hours prior to the ten-day testing session. All testing was done between the hours of 2 p.m. and 11 p.m. and care was taken to test all three littermates in succession and on the same day. It was assumed that since the split-litter technique was used, there were no initial significant differences between the littermates on the physiological and behavioural measures.

The first part of the experiment consisted in the obtention of <u>PEP</u>s. Subjects were securely restrained but allowed to breathe comfortably and see the photic stimulator. Once the animal was tightly held in place, only minimal struggling was noted, usually being replaced by freezing behaviour. Two needle electrodes were then inserted into the scalp and a reference and ground electrode into the tail. The two head electrodes were placed over the right hemisphere approximately 2 mm. apart, on a plane half-way between the midline and the base of the right ear lobe, the posterior electrode being slightly anterior to the inion. It is felt that this electrode placement approximates that used by Edwards[2] in his original study. Further care was taken to

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[2] H.P. Edwards, <u>Effects of Early Rearing in Differential Environments on the Albino Rat's Photic Evoked Potentials</u>, doctoral dissertation presented to the Faculty of Psychology and Education of the University of Ottawa, Ontario, 1967, p.35.

obtain an impedance reading of 15k to 20k for all subjects. The animal was then placed twelve inches away from the photo stimulator, the room was darkened and 140 light flashes were administered randomly but separated by a minimum time interval of two seconds.

In an attempt to eliminate as much as possible myogenic contaminants, each gerbil's EEG was constantly monitored so as to avoid stimulating while muscular movement prevailed. The first 70 and second 70 stimuli were then examined visually as a rough indicator of reliability. Of all the subjects' PEPs, only one was considered to be of borderline constancy. This animal was immediately returned to its cage and retested a short time later.

Two quantitative measures of emotionality were taken during the PEP recording session. This consisted in counting the number of pellets defecated both during the initial restraining procedure and during the obtention of PEPs. Prior to the electrode insertion, a tape recorder was turned on so as to pick up sounds emitted by the animal. Each squealing sound in the audible range received a score of 1. These two scores were then added, averaged for each animal, and compared between the three littermates.

At the end of PEP recording, the lights were turned on and the animal was given a one-minute adaptation period. An electrocardiogram was then obtained, using the anterior scalp electrode and the reference and ground electrodes situated respectively in the skin of the upper and lower parts of the tail. The frequency count of a 15 sec. sample was used for final analysis, this score being multiplied by 4 so as to obtain the number of beats per minute. Statistical analysis between littermates was then performed.

PEP analysis was carried out on a PDP8/1 Digital Laboratory Peripheral computer manufactured by the Digital Equipment Corporation using the N.T. binary program. For each subject, the first 70 and second 70 stimuli were replayed independently from the original magnetic tape and re-analyzed with the use of a Krohn-Hite model 3342 filter set at 3-50 Hz and a 3300A Function Generator. Samples of data filtered between 3-30 Hz and 3-40 Hz proved less satisfactory than the original 3-50 Hz used. A 3734A Electronic Counter was set at 2 milliseconds per data point. The PEPs were displayed on an RM 503 Oscilloscope and drawn out on a Moseley 7035B X-Y recorder. The data were then recorded on punch tape for further reference. The computer was programmed to yield the mean, standard deviation and total EEG amplitude of each waveform as well as the latency and amplitude of each peak and trough, expressed in milliseconds and millivolts respectively.

Further analysis consisted of adding the waveforms of all animals in each group, resulting in three group PEPs illustrated in Figure 2. On the basis of these and on the

Figure 2. - Group Photic Evoked Potentials Obtained from Five Fully Enriched, Five Visually Enriched and Five Deprived Gerbils at Three Months of Age.

recommendations made in the literature that an event should be of high amplitude and well-defined, it was decided to accept for statistical analysis the two peaks of highest amplitude above and the peak of highest amplitude below one standard deviation from the mean.

There now remains to discuss the procedure employed in obtaining the behavioural measures.

The exploratory behaviour task was conducted following the <u>PEP</u>, heart rate and emotionality measures. This consisted simply in placing each animal in the lower right-hand side compartment of the maze and counting the number of units it covered in a three-minute period.

For the learning task, each animal was placed into the left-hand side compartment of the shuttle-box and allowed a thirty-second adaptation period. The apparatus was then turned on, the criterion of learning being nine out of ten avoidance responses and the total score being the number of trials needed to achieve this criterion. Pre-training to escape learning could not be carried out in view of the fact that a few enriched animals gave only one escape response followed by nine successive avoidance responses. An animal failing to reach the criterion by the two-hundredth trial received a score of 200.

The final part of the experiment consisted in estimating the activity level of each animal. Each gerbil was placed into the activity cage for exactly fifteen minutes, the score being the number of centimeters as measured from the cumulative recorder.

4. Statistical Analysis.

So as to check for significant differences between the three groups of gerbils on the previously mentioned dependent variables of this study, a one-way analysis of variance solution was adopted, following the procedure outlined by Dayhaw.[3] The formulas used in calculating, Total, Between and Within variances respectively are the following: $\Sigma X^2 - T^2/N$; $(\Sigma T_k^2)/n - T^2/N$; and $\Sigma X^2 - (\Sigma T_k^2)/n$, with k-1 degrees of freedom for Between variance and N-k degrees of freedom for Within variance.

Where this solution yields overall significant differences, a t test as suggested by Dayhaw[4] will be used:

$$t = \sqrt{2\sigma^2/n}$$

<u>PEP</u> reliability will be established by correlating the latency value of each event in the first 70 stimuli with

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[3] L.T. Dayhaw, <u>Manuel de Statistique</u>, éditions de l'Université d'Ottawa, Ottawa, Canada, 1966, p. 413-415.

[4] <u>Ibid</u>., p. 416-417.

the latency value of the same event in the second 70 stimuli by means of the Pearson "r" formula:[5]

$$r_{xy} = \frac{N\Sigma XY - \Sigma X\ \Sigma Y}{\sqrt{N\Sigma X^2 - (\Sigma X)^2}\ \sqrt{N\Sigma Y^2 - (\Sigma Y)^2}}$$

The same procedure will be repeated for PEP amplitude values.

The level of significance of these coefficients will be estimated by means of a t test for a sample smaller than thirty, as suggested by Bruning and Kintz.[6] The following formula, with N-2 degrees of freedom, will thus be used:

$$t = r\sqrt{(N - 2) / (1 - r^2)}$$

Spearman "rho" coefficients will also be calculated on the same data so as to provide additional reliability evidence. The formula used is the following:[7]

$$\text{rho} = 1 - \frac{6\ \Sigma\ D^2}{N\ (N^2\ -1)}$$

where D is the difference score between each X and Y pair.

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[5] Ibid., p. 126.

[6] J.L. Bruning and B.L. Kintz, Computational Handbook of Statistics, Glenview, Ill., Scott, Foresman and Co., 1968, p. 155.

[7] Ibid., p. 156-158.

The level of significance of these coefficients will be estimated by means of a t test for a sample smaller than thirty. The following formula with N-2 degrees of freedom will thus be used:[8]

$$t = \text{rho} \sqrt{N - 2 / 1 - \text{rho}^2}$$

Having discussed the sample, the tools, the experimental procedure and the analysis of the data, the writer now turns to the presentation and discussion of results.

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[8] *Ibid*., p. 158-159.

CHAPTER III

PRESENTATION AND DISCUSSION OF RESULTS

1. Results of the Tests of Significance.

This section repeats the null hypotheses stated in Chapter I and presents the appropriate statistical results following each null hypothesis. The statistics used were a one-dimension analysis of variance solution which, when yielding a significant value, was followed by a t test for differences among several means.

The major hypothesis states that there are no significant differences in the PEP waveforms (latencies and amplitude) of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched, and Deprived environments.

All PEP data were obtained in accordance with the procedure outlined in Chapter II.

As can be seen from Table I, the PEP data were considered sufficiently reliable, as assessed by both Pearson "r" and Spearman "rho" coefficients. The reliability coefficients for "r" and "rho" respectively were .95 and .97 for Event 1, .96 and .91 for Event 2, .83 and .90 for Event 3, and .74 and .76 for the amplitude values. The comparison of "r" and "rho" values further suggests that the use of the

Table I.-

Test-Retest[a] Reliability Coefficients of PEP Latency[b] and Amplitude[c] Values Using Pearson "r" and Spearman "rho".

Comparison	"r"	Significance	"rho"	Significance
E1	.95	.001	.97	.001
E2	.96	.001	.91	.001
E3	.83	.001	.90	.001
Amplitude	.74	.01	.76	.01

[a] Pearson "r" between first 70 photic stimuli and second 70 photic stimuli for the fifteen gerbils.

[b] measured in milliseconds.

[c] measured in millivolts and consisting of the EEG amplitude divided by the PEP standard deviation.

Pearson "r" as an index of reliability is justified in this study.

The mean PEP latency and amplitude measures of each group were compared using a one-dimension analysis of variance solution with two and twelve degrees of freedom for Between and Within variance, respectively.

For Event 1, the mean PEP latency of the Fully Enriched group was 104 msec.; that of the Visually Enriched group, 103 msec.; and that of the Deprived group, 103 msec.; the F value of .0053 being non-significant at the .01 level of confidence.

For Event 2, the mean PEP latency of the Fully Enriched group was 260.8 msec.; that of the Visually Enriched group, 246.4 msec.; and that of the Deprived group, 268 msec.; the F value of .21 being non-significant at the .01 level.

For the negative event labelled Event 3, the mean PEP latency of the Fully Enriched group was 162.8 msec.; that of the Visually Enriched group, 157.8 msec.; and that of the Deprived group, 169 msec.; the F avlue of .20 being non-significant at the .01 level.

For the amplitude values, the mean PEP amplitude ratio of the Fully Enriched group was 3.34 mv.; that of the Visually Enriched group, 3.72 mv.; and that of the Deprived group, 3.89 mv.; the F value of .30 being non-significant at the .01 level of probability. These results are presented in Table II.

Table II.-

Comparison of Mean PEP Latency[a] and Amplitude[b] Values Between Fully Enriched, Visually Enriched and Deprived Groups of Gerbils, Using a One-Dimension Analysis of Variance Solution.

Comparison	Mean (n:5)		F(2,12)	Significance
E1	FE	104.0	.0053	N.S.
	VE	103.0		
	D	103.0		
E2	FE	260.8	.21	N.S.
	VE	246.4		
	D	268.0		
E3	FE	162.8	.20	N.S.
	VE	157.8		
	D	169.0		
Amplitude	FE	3.34	.30	N.S.
	VE	3.72		
	D	3.89		

[a] measured in milliseconds.

[b] measured in millivolts and consisting of the EEG amplitude divided by the PEP standard deviation.

Based on the above results, the first major hypothesis of this investigation is not rejected.

The second major hypothesis in its null form reads that there are no significant differences in the learning ability of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched, and Deprived environments.

The statistical comparison again consisted of a one-dimension analysis of variance solution. The mean number of trials to criterion was 12.4 for the Fully Enriched group; 23 for the Visually Enriched group; and 131 for the Deprived group; the F value of 8.76 being significant at the .01 level of probability (Table III).

Further comparisons using a t test for differences among several means yielded differences of 10.6 between the Fully Enriched and Visually Enriched groups; of 118.6 between the Fully Enriched and Deprived groups; and of 108 between the Visually Enriched and Deprived groups (Table IV). The second and third comparisons were significant at the .01 level of probability, whereas the first was not.

On the basis of these results, the second major hypothesis is thus rejected.

Table III.-

Comparison of Mean Learning Scores[a] Between Fully Enriched, Visually Enriched and Deprived Groups of Gerbils, Using a One-Dimension Analysis of Variance Solution.

Group	Mean(n:5)	F(2,12)	Significance
FE	12.4		
VE	23.0	8.76	.01
D	131.0		

[a] obtained in a shuttle-box conditioning task as the total number of trials required to reach a criterion performance of nine out of ten avoidance responses.

Table IV.-

Comparison of Mean Learning Scores Between Fully Enriched, Visually Enriched and Deprived Groups of Gerbils, Using a t Test for Differences among Several Means.

Groups Compared (n:5)	Means Compared	Diff.	Min. Sig. Diff(P.01)	Sig.
FE - VE	12.4-23.0	-10.6	95.8	N.S.
FE - D	12.4-131.0	-118.6	95.8	.01
VE - D	23.0-131.0	-108.0	95.8	.01

The first minor hypothesis, expressed in its null form, states that there are no significant differences in the amount of exploration of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched, and Deprived environments.

A comparison of the mean exploration scores yielded values of 56.2 for the Fully Enriched gerbils; 51.8 for the Visually Enriched gerbils; and 24.4 for the Deprived gerbils; the F value of 13.82 being significant at the .001 level of confidence (Table V). The difference between the means of the Fully Enriched and Visually Enriched groups was 4.4;; that of the Fully Enriched and Deprived groups, 31.8; and that of the Visually Enriched and Deprived groups, 27.4. While the first comparison was not significant, the second and third comparisons were significant at the .001 and .01 level of probability, respectively (Table VI).

Based on these results, the first minor hypothesis is thus rejected.

The second minor hypothesis, in its null form, states that there are no significant differences in the degree of emotionality of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched, and Deprived environments.

A comparison of the mean emotionality scores yielded values of 10.4 for the Fully Enriched animals; 9 for the

Table V.-

Comparison of Mean Exploration Scores[a] Between Fully Enriched Visually Enriched and Deprived Groups of Gerbils, Using a One-Dimension Analysis of Variance Solution.

Group	Mean(n:5)	F(2,12)	Significance
FE	56.2		
VE	51.8	13.82	.001
D	24.4		

[a] obtained in an exploration task as the total number of units covered in a three-minute period.

Table VI.-

Comparison of Mean Exploration Scores Between Fully Enriched, Visually Enriched and Deprived Groups of Gerbils, Using a t Test for Differences among Several Means.

Groups Compared(n:5)	Means Compared	Diff.	Min. Sig. Diff. P.01	P.001	Sig.
FE - VE	56.2-51.8	4.4	20.01	28.28	N.S.
FE - D	56.2-24.4	31.8	20.01	28.28	.001
VE - D	51.8-24.4	27.4	20.01	28.28	.01

Visually Enriched animals; and 3.9 for the Deprived animals; the F value of 3.28 being non-significant at the .01 level of probability (Table VII).

Consequently, the second minor hypothesis is not rejected.

The third minor hypothesis expressed in its null form states that there are no significant differences in the activity levels of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched, and Deprived environments.

The Fully Enriched animals obtained a mean score of 21.4; the Visually Enriched, 16.6; and the Deprived, 10.4; the F value of 2.58 being non-significant at the .01 level (Table VIII).

The third minor hypothesis is therefore not rejected.

The fourth minor hypothesis stated in its null form reads that there are no significant differences in the heart rate levels of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched and Deprived environments.

A comparison of the mean heart rate scores yielded values of 132 for the Fully Enriched gerbils; 181.6 for the Visually Enriched gerbils; and 176.8 for the Deprived gerbils; the F value of 3.47 being non-significant at the .01 level of confidence (Table IX).

Based on these results, the fourth minor hypothesis is therefore not rejected.

Table VII.-

Comparison of Mean Emotionality Scores[a] Between Fully Enriched, Visually Enriched and Deprived Groups of Gerbils, Using a One-Dimension Analysis of Variance Solution.

Group	Mean(n:5)	F(2,12)	Significance
FE	10.4	3.28	N.S.
VE	9.0		
D	3.9		

[a] obtained by averaging the number of pellets defecated and the number of squeals emitted during the restraining and PEP recording session.

Table VIII.-

Comparison of Mean Activity Scores[a] Between Fully Enriched, Visually Enriched and Deprived Groups of Gerbils, Using a One-Dimension Analysis of Variance Solution.

Group	Mean(n:5)	F(2,12)	Significance
FE	21.4		
VE	16.6	2.58	N.S.
D	10.4		

[a] obtained in an activity cage task as the number of millimetres indicated on a recorder.

Table IX.-

Comparison of Mean Heart Rate Scores[a] Between Fully Enriched, Visually Enriched and Deprived Groups of Gerbils, Using a One-Dimension Analysis of Variance Solution.

Group	Mean(n: 5)	F(2,12)	Significance
FE	132.0		
VE	181.6	3.47	N.S.
D	176.8		

[a] number of heartbeats per minute as recorded on an electrocardiogram.

2. Discussion of Results.

The superiority in learning ability displayed by both enriched groups of gerbils supports Hebb's original contention of the adult problem-solving superiority of animals with greater early perceptual experience in a spacious social environment.[1]

However, since no significant differences were obtained in the number of learning trials to criterion between the Fully Enriched and Visually Enriched groups, it appears that the additional auditory, olfactory and tactile perceptual experience has little effect on subsequent learning ability and that the visual modality is the most relevant one for sensory enrichment.

The results thus support the previous findings of faster learning in enriched animals as noted by Schweikert and Collins,[2] Clarke *et al*.[3] Bingham and Griffiths,[4]

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[1] D.O. Hebb, "The Effects of Early Experience on Problem-Solving at Maturity", *The American Psychologist*, Vol. 2, 1947, p. 307.

[2] G.E. Schweikert, and G. Collins, "The Effects of Differential Postweaning Environments on Later Behavior in the Rat", *The Journal of Genetic Psychology*, Vol. 109, 1966, p. 262.

[3] R.S. Clark, W. Heron, M.L. Fetherstonhaugh, D.G. Forgays and D.O. Hebb, "Individual Differences in Dogs: Preliminary Report on the Effects of Early Experience", *Canadian Journal of Psychology*, Vol. 5, 1951, p. 156.

[4] W.E. Bingham, W.J. Griffiths, "The Effect of Differential Environments During Infancy on Adult Behaviour in the Rat", *Journal of Comparative and Physiological Psychology*, Vol. 45, 1952, p. 311.

Reynolds,[5] Thompson and Heron[6] and Forgays and Forgays[7] and extend them to the Mongolian gerbil.

The results also support Melzack's[8] findings with dogs, i.e. that restricted animals require more shocks to reach the selected avoidance criterion. The differences in rate of learning obtained in the present study are also in the same direction as those noted by Edwards _et al_.[9] on a discrimination task using the albino rat as subject.

The results of the exploration task, on the other hand, suggest that the additional effect of olfactory, auditory and tactile enrichment may favour greater adult exploratory behaviour or perceptual curiosity.

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[5] H.H. Reynolds, "Effects of Rearing and Habituation in Social Isolation on Performance of an Escape Task", _Journal of Comparative and Physiological Psychology_, Vol. 56, 1963, p. 520.

[6] W.R. Thompson and W. Heron, "The Effects of Restricting Early Experience on the Problem-Solving Capacity of Dogs", _Canadian Journal of Psychology_, Vol. 8, 1964, p. 24.

[7] D.G. Forgays and J.W. Forgays, "The Nature of the Effect of Free-Environment Experience in the Rat", _Journal of Comparative and Physiological Psychology_, Vol. 45, 1952, p. 327-328.

[8] R. Melzack and T.H. Scott, "The Effects of Early Experience on the Response to Pain", _Journal of Comparative and Physiological Psychology_, Vol. 50, 1957, p. 160.

[9] H.P. Edwards, W.F. Barry and J.O. Wyspianski, "Effect of Differential Rearing on Photic Evoked Potentials and Brightness Discrimination in the Albino Rat", _Developmental Psychobiology_, 1969, Vol. 2, No. 3, 1970, p. 134.

It is noteworthy that the obtained exploration data are in the opposite direction of most previous studies concerning early sensory enrichment-deprivation and later exploratory behaviour. More specifically, the findings do not support the generally reported negative correlation between early sensory restriction and later perceptual curiosity as reflected in higher exploration scores.[10]

Consequently, the results of the present study cannot be incorporated within the Dember and Earl[11] theoretical framework which contends that the problem-solving superiority of enriched animals arises because of the decreased novelty of the test situation for them as reflected in lower exploration scores and a hypothesized lower distractibility level.

Based on behavioural observations about to be reported, the present writer proposes that qualitative differences in emotionality brought about by the differential environments may have a decisive influence on later learning capacity and exploratory behaviour.

It was noted during the experiment that the deprived animals exhibited a cautious, hesitant attitude when placed

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[10] R. Melzack, "Effects of Early Experience on Behaviour: Experimental and Conceptual Considerations", in Hoch and Zubin (eds.), Disorders of Perception, New York, Grune and Stratton, 1965, p. 273-274.

[11] W.N. Dember and R.W. Earl, "Analysis of Exploratory, Manipulatory and Curiosity Behaviours", Psychological Review, Vol. 64, No. 2, 1957, p. 91-92.

into the exploration maze; they frequently displayed fearlike crouching responses and seemed more preoccupied with the black and white vertical lines painted on the walls of the maze than their enriched littermates. The more relaxed attitude of the enriched animals was reflected in their more playful behaviour which in some cases was manifested in the amusing tendency to jump over maze partitions instead of using the standard openings to gain access to the various compartments. Also noted in these animals was frequent grooming and standing on hind legs, seemingly so as to "look over" the entire situation.

Similar behavioural trends were apparent in the shuttle-box learning task where the more relaxed, efficient attitude of the enriched gerbils was again contrasted with the disorganized behaviour of the deprived ones. The enriched animals remained close to the door after crossing from the shocked compartment to the unshocked one, seemingly so as to be prepared for rapid escape or avoidance at the next trial. The deprived animals, on the other hand, attempted to take refuge from the shock by withdrawing to the section of the compartment farthest from the door and lying down. Also noted on the part of the deprived animals was extreme fright to the buzzer sound preceding the shock, as manifested in impulsive jumping where the animal would become totally inadequate, crashing at full force into the walls and ceiling of the compartment instead of going to the unshocked side through the open door.

Added to the fact that no significant differences in arousal were obtained on PEP amplitude and heart rate between the three groups, it is proposed that early sensory deprivation and enrichment may be producing important differences in fear rather than arousal. Such fear on the part of the deprived animals is inferred by fewer exploratory tendencies and gross disorganization and inadequate coping ability upon subsequent adult exposure to novel stimulation. Within the Hebbian framework, these differences would be due, in the case of the impoverished animals, to their lack of familiarity with patterned stimulation and experience at an early age.

Concerning the quantitative measures of emotionality as such, no significant differences were found between the three groups, although the F value approached the .05 level, despite obvious qualitative differences in emotionality between the littermates. The writer feels that a quantitative evaluation of emotionality remains quite subjective and may not reflect true group differences on this variable because such behaviour seems more qualitative than quantitative.

Apart from the previously mentioned differences in emotionality, it was noted, in accordance with Melzack's[12]

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[12] Melzack, op. cit., p. 273-274.

observations, that deprived animals manifested little response to pain during initial restraining, electrode placement and subsequent PEP recording, and exhibited more freezing behaviour than their enriched littermates. Simple handling, however, was oftentimes accompanied by violent struggling and aggression taking the form of biting and the emission of "snorting" sounds. The fear and aggression displayed by the deprived gerbils appears in accord with the Denenberg *et al.*[13] observations that enriched rats are less emotional than their control littermates as well as those of Menzel *et al.*[14] who noted similar patterns with chimpanzees. The generally reported findings of extreme crouching, fright, withdrawal and aggression on the part of various species of restricted animals are thus extended to the Mongolian gerbil.

The absence of differences in PEP amplitude and heart rate between the three groups does not support Melzack's contention that deprived animals are more physiologically aroused (lowered amplitude) and consequently less attentive to

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[13] V.H. Denenberg, G.G. Karas, K.M. Rosenberg, and S.F. Schell, "Programming Life Histories: An Experimental Design and Initial Results", *Developmental Psychobiology*, Vol. 1, No. 1, 1968, p. 4.

[14] E.W. Menzel, R.K. Davenport, C.M. Rogers, "Effects of Environmental Restriction Upon the Chimpanzee's Responsiveness in Novel Situations", *Journal of Comparative and Physiological Psychology*, Vol. 56, No. 2, 1963, p. 329-333.

environmental cues.[15] Along similar lines, Fuller[16] has suggested that isolated animals did poorly on problem-solving tasks because of increased CNS arousal and that these animals responded to average stimulation as normally reared animals responded to violent stimulation. While these views appear defensible behaviourally, they are not backed up by the PEP, heart rate and activity data which reflect no arousal or activity difference between the groups, despite the obtention of significant learning ability differences in a conditioning task. Thus, the positive correlation between activation and level of performance as reported by Malmo[17] is not supported by the results of this study.

As previously mentioned in the presentation of results, no significant differences in PEP latency were obtained between the three groups for the three events considered. Thus, in this study, the PEP data do not reflect the possible anatomical-chemical differences noted by Rosenzweig,[18]

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[15] R. Melzack and S.K. Burns, "Neurophysiological Effects of Early Sensory Restriction", Experimental Neurology, Vol. 13, 1965, p. 171.

[16] J.L. Fuller, "Experiential Deprivation and Later Behavior", Science, Vol. 158, No. 3807, 1967, p. 1645.

[17] R.B. Malmo, "Activation: A Neuropsychological Dimension", Psychological Review, Vol. 66, No. 6, 1959, p. 367-386.

[18] M.R. Rosenzweig, "Environmental Complexity, Cerebral Change, and Behavior", American Psychologist, Vol. 21, 1966, p. 321-322.

Altman[19] and Essman.[20] The data are not consistent with Bradley's[21] findings of longer PEP latencies in cretinous rats as compared to normal littermates. Thus, the present experiment does not reproduce the Edwards *et al.*[22] findings with albino rats of differences in brain functioning efficiency brought about by the differential rearing conditions. More generally, the experimental results do not replicate the Chalke and Ertl[23] and Taylor[24] findings with human subjects concerning the correlation between behavioural intelligence and biological intellectual efficiency as measured by PEPs.

The present PEP results may indicate either that the issue of the early effects of differential environments on brain activity is a species specific one and cannot be

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[19] J. Altman, R.B. Wallace, W.J. Anderson, G.D. Pas, "Behaviorally Induced Changes in Length of Cerebrum in Rats", *Developmental Psychobiology*, Vol. 11, No. 2, 1968, p. 112.

[20] J.P. Essman, "Differences in Locomotor Activity and Brain Serotonin Metabolism in Differentially Housed Mice", *Journal of Comparative and Physiological Psychology*, Vol. 66, No. 1, 1968, p. 244.

[21] P.B. Bradley, J.T. Eayrs, and N.M. Richards, "Factors Influencing Potentials in Normal and Cretinous Rats", *EEG and Clinical Neurophysiology*, Vol. 17, 1964, p. 312.

[22] H.P. Edwards, W.F. Barry and J.O. Wyspianski, "Early Environment Effects on Rat Photic Evoked Potentials: A Preliminary Study", *Revista Interamericana de Psicologia*, Vol. 2, 1968, p. 88-89.

[23] F.R. Chalke and J.P. Ertl, "Evoked Potentials and Intelligence", *Life Sciences*, Vol. 4, No. 13, 1965, p. 1319.

[24] N. Taylor, *Evoked Potential Latencies and Psychometric Intelligence*, unpublished Master's thesis presented to the School of Psychology and Education of the University of Ottawa, Ontario, 1966, ix-76 p.

generalized to the Mongolian gerbil or that we have not, as of yet, discovered the ideal procedure revealing the true PEP differences between the groups.

A third possibility which could account for the negative PEP findings particularly for the Fully Enriched animals may reside in the general area of sensory overstimulation, in the sense that the investigator may have overdone the enrichment procedure. This may have resulted in an overloading of afferent pathways because of simultaneous overstimulation from the various modalities involved, possibly resulting in a relatively lowered functioning of inhibitory mechanisms regulating cortical bombardment, while not being evident in simple conditioning tasks requiring little use of integrative ability.

A study deliberately concerned with concentrated overstimulation at an early age could perhaps represent a significant and practical contribution. More specifically, early differential environments and possible overstimulation may result in a differential functioning of inhibitory and habituation mechanisms to later adult stimulation. In this context, a longitudinal differential environment animal study using adult OR habituation rates with simultaneous PEP recording to the same light flash as dependent variables could be a worthwhile endeavour. The writer, of course, realizes the methodological and technical difficulties that would have to to ironed out before such a study became possible. The investigation could possibly be conducted in the framework of Hernandez-Peon's hypotheses which indicate that the regulation of centrifugal inhibition of non-significant sensory signals at their entrance to the CNS may be altered in some pathological states, thus reflecting failure of afferent neuronal habituation and resulting in excessive entrance of sensory signals to the brain.

SUMMARY AND CONCLUSIONS

Based on previous albino rat studies conducted at the University of Ottawa, the aim of the present investigation was to assess the effects of differential environments on the photic evoked potentials, arousal and behaviour of male Mongolian gerbils at the age of three months.

The first major hypothesis to be tested stated that there are no significant differences in the PEP waveforms (latencies and amplitude) of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched and Deprived environments. The second major hypothesis stated that there are no significant differences in the learning ability of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched and Deprived environments. Four minor hypotheses expressed in their null form were concerned with the possible effects of differential environments on exploratory behaviour, emotionality, activity and heart rate between the three groups of gerbils at the age of three months.

A one-dimension analysis of variance solution was used as statistical test of significance for all hypotheses. Where the overall comparisons yielded significant results at the .01 level of confidence, a t test was employed to evaluate the individual differences. The photic evoked potential waveforms as well as the activity and heart rate data yielded no significant results and these hypotheses were thus not rejected. The emotionality assessment, while not being quantitatively significant, revealed important qualitative differences. The significant differences obtained in learning ability and exploratory behaviour permitted the rejection of both these hypotheses. In the latter case, however, the direction of the difference was not as expected and was explained on the basis of qualitative emotionality differences between the groups. The theoretical viewpoint of sensory overloading at an early age was discussed as a possible explanation for the lack of significant differences observed between the three groups of gerbils on the PEP and arousal data.

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It this relatively recent publication, the authors report that rats subjected to a complex visual discrimination training, an enriched social environment and handling display longer cerebral hemispheres than control littermates. These results can be interpreted in support of the Rosenzweig *et al.* findings.

Beach, F.A. and J. Jaynes, "Effects of Early Experience Upon the Behaviour of Animals", *Psychological Bulletin*, Vol. 51, 1954, p. 239-263.
The authors present a thorough review of the literature concerning the effects of early experience on later behaviour. They interpret the findings in this area in terms of the sensory and perceptual development of the animal, as Hebb had suggested.

Bradley, P.B., J.T. Eayrs and N.M. Richards, "Factors Influencing Potentials in Normal and Cretinous Rats", *EEG and Clinical Neurophysiology*, Vol. 17, 1964, p. 308-313.
The most significant findings of this study are that the latency between the stimulus and the beginning of the negative wave and the duration of the negative wave of the evoked potential are both longer in cretinous rats than in normal rats. In addition, the amplitude of the evoked potential of the cretinous rats is significantly less than in the normal.

Brown, R.T., "Early Experience and Problem-Solving Ability", *Journal of Comparative and Physiological Psychology*, Vol. 65, No. 3, 1968, p. 433-440.
Based on the performance of four differentially reared groups of rats on three exploration tests, the author concludes that the rearing condition does not affect the amount of exploration. The superior performance of the three relatively enriched groups on the Hebb-Williams maze is ascribed to their greater use of extrafield cues.

Chalke, F.R. and J.P. Ertl, "Evoked Potentials and Intelligence", *Life Sciences*, Vol. 4, No. 13, 1965, p. 1319-1322.
The authors hypothesize that the evoked potential latencies reflect biological efficiency and information processing ability. The results replicate the original findings of Ertl but the sample size is generally small, particularly for the low I.Q. subjects.

Clarke, R.S., W. Heron, M.L. Fetherstonhaugh, D.G. Forgays and D.O. Hebb, "Individual Differences in Dogs: Preliminary Report on the Effects of Early Experience", Canadian Journal of Psychology, Vol. 5, 1951, p. 150-156.

The authors conclude that dogs reared under deprived conditions appear deficient in later learning ability.

Denenberg, V.H., G.G. Karas, K.M. Rosenberg, S.F. Schell, "Programming Life Histories: An Experimental Design and Initial Results", Developmental Psychobiology, Vol. 1, No. 1, 1968, p. 3-9.

The authors state that rats reared in an enriched environment in early life engage in more complex social interactions and appear less emotional in laboratory tests than their deprived littermates.

Edwards, H.P., W.F. Barry and J.O. Wyspianski, "Early Environment Effects on Rat Photic Evoked Potentials: A Preliminary Study", Revista Interamericana de Psicologia, Vol. 2, No. 2, 1968, p. 85-92.

In this preliminary study, the authors compare the mean photic evoked potential latencies of enriched and impoverished groups of albino rats on each of three occasions at two-week intervals following the establishment of differential environments. The enriched group consistently displayed shorter latencies than the impoverished group for the event considered. These results are interpreted by the authors as differences in brain functioning efficiency brought about by differential rearing.

--------, "Effect of Differential Rearing on Photic Evoked Potentials and Brightness Discrimination in the Albino Rat", Developmental Psychobiology, Vol. 2, No. 3, 1970, p. 133-138.

This is the most recent publication by these authors and consists of two separate experiments on albino rats. The results of both experiments corroborate the findings of their initial study. In the second experiment, after nine weeks of differential rearing the enriched group was significantly superior on a discrimination task.

Ertl, J.P., Intra-Cortical Delay and Intelligence, unpublished Master's thesis presented to the School of Psychology and Education of the University of Ottawa, Ontario, 1961, viii-41 p.

Ertl's dissertation is the first successful study to indicate a possible relationship between visual evoked potentials and human psychometric intelligence.

Ertl, J.P. and E.W.P. Schafer, "Brain Response Correlates of Psychometric Intelligence", Nature, Vol. 223, July 1969, p. 421-422.

This is one of the latest studies by Ertl and Schafer using a substantial sample. They report that the latencies of the third and fourth peaks of the photic evoked potential waveform correlate very significantly with Otis, PMA and WISC intelligence scores.

Fox, M.W., "The Effects of Short-Term Social and Sensory Isolation Upon Behavior, EEG and Averaged Evoked Potentials in Puppies", Physiology and Behavior, Vol. 2, 1967, p. 145-151.

This study, using dogs as subjects, reports the effects of a one-week period of isolation at an early age on a number of psychophysiological and behaviour tests. Hyperactive EEG patterns, nonspecific exploration and curiosity were noted upon emergence from isolation. The results are interpreted in terms of Melzack's findings concerning level of arousal and early sensory deprivation.

Fuller, J.L., "Experiential Deprivation and Later Behavior", Science, Vol. 158, No. 3807, 1967, p. 1645-1652.

The author interprets the inferior problem-solving capacity of isolated animals on the basis of heightened arousal which interferes with the adequate filtering of inputs in the learning situation. The theory largely reflects Ronald Melzack's view on sensory deprivation and arousal.

Hebb, D.O., "The Effects of Early Experience on Problem-Solving at Maturity", The American Psychologist, Vol. 2, 1947, p. 306-307.

In this short summary of his findings Hebb reports that the rats reared in a varied environment or blinded late in their development display superior problem-solving ability on Hebb-Williams mazes than deprived rats or rats blinded early in their development.

Hernandez-Peon, R., C. Guzman-Flores, M. Alcaraz and A. Fernandez-Guardiola, "Photic Potentials in the Visual Pathway During 'Attention' and Photic 'Habituation'", Federation Proceedings of the American Physiological Society, Vol. 15, 1956, p. 91-92.

The investigators report that when an animal's attention is attracted by non-visual stimuli, the photic evoked potentials recorded in the visual cortex, lateral geniculate body and optic tract are typically reduced in amplitude. The authors hypothesize that sensory inhibition of irrelevant stimuli leads to the favouring of the object by the selective exclusion of incoming signals whereas the loss of plastic inhibition brings about a state of diffuse central hyperexcitability.

Hymovitch, B., "The Effects of Experimental Variations on Problem-Solving in the Rat", The Journal of Comparative and Physiological Psychology, Vol. 45, 1952, p. 313-321.

This study is concerned with the issue of critical periods of sensory enrichment and deprivation. The author concludes that if free environment experiences are to be favourable to later maze-solving ability, they must take place early in life.

La Torre, J.C., "Effect of Differential Environmental Enrichment on Brain Weight and on Acetylcholinesterase and Cholinesterase Activities in Mice", Experimental Neurology, Vol. 22, 1968, p. 493-503.

The results of this study using mice as subjects corroborate the findings of the Rosenzweig *et al.* group with rats.

Malmo, R.B., "Activation: A Neuropsychological Dimension", Psychological Review, Vol. 66, No. 6, 1959, p. 367-386.

The author states that the level of performance on learning tasks rises monotonically with increasing activation level up to an optimal point beyond which a fall in level of performance is obtained; in addition, the longer the period of deprivation, the higher is the heart rate under conditions of novel stimulation.

Melzack, R., "Effects of Early Perceptual Restriction on Simple Visual Discrimination", Science, Vol. 137, 1962, p. 978-979.

The author reports that dogs reared from infancy to maturity in environments that restrict their visual input display greater difficulties than their control littermates on a simple discrimination task. The difficulties encountered by the restricted animals are attributed to heightened arousal and inadequate selection of relevant cues from the environment.

--------, "Effects of Early Experience on Behaviour: Experimental and Conceptual Considerations", in Hoch and Zubin (eds.), Disorders of Perception, New York, Grune and Stratton, 1965, p. 271-299.

This article discusses the detrimental effects of early sensory restriction on the adult emotional behaviour of the dog.

Melzack, R. and S.K. Burns, "Neurophysiological Effects of Early Sensory Restriction", Experimental Neurology, Vol. 13, 1965, p. 163-175.

The authors report that the EEG and evoked potentials of restricted dogs display lowered amplitudes when the animals examine a novel environment through their open cage doors; the findings are interpreted in terms of heightened arousal on the part of the deprived dogs.

Pickenhain, L. and F. Klingberg, "Behavioural and EEG Changes During Avoidance Conditioning to Light Flashes in the Rat", EEG and Clinical Neurophysiology, Vol. 18, 1965, p. 464-476.

The authors mention that the evoked potential amplitudes diminish during motor activity of the rat, especially during orienting movements. They interpret this finding in terms of excessive non-specific activation.

Reynolds, H.H., "Effects of Rearing and Habituation in Social Isolation on Performance of an Escape Task", Journal of Comparative and Physiological Psychology, Vol. 56, 1963, p. 520-525.

Based on the performance of rats on an escape task in a shocked Y-maze, the author concludes that rats reared in isolation are inferior problem-solvers as compared with companionship-reared rats. He attributes the detrimental effect of isolation on later behaviour to continued stress on the part of the experimental isolates.

Rosenzweig, M.R., "Environmental Complexity, Cerebral Change and Behavior", American Psychologist, Vol. 21, 1966, p. 321-332.

This article summarizes and synthesizes almost all of the author's work. He reports that enriched rats exhibit greater brain weight particularly in the occipital region, a greater cortical/subcortical weight ratio as well as a higher level of total enzymatic activity in comparison to their deprived littermates. In the cortex, however, since the increase in enzymatic activity is less than the increase in tissue weight, the activity per unit weight decreases in the enriched animals.

Shaw, J.A. and A.F. Thompson, "Inverse Relation Between Evoked Cortical Association Responses and Behavioural Orienting to Repeated Auditory Stimuli", Psychonomic Science, Vol. 1, 1964, p. 399-400.

In this ingenious study, the authors compare the amplitude of the auditory evoked response recorded from cats by means of implanted cortical electrodes to the degree of behavioural orienting to the same stimulus. The results suggest that as the arousal decreases, the amplitude of the evoked association response increases.

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Steinberg, R.H., "Alternations of Averaged Photic Evoked Potentials in Cat Visual Cortex During Repetitive Stimulation", EEG and Clinical Neurophysiology, Vol. 18, 1965, p. 378-391.

The author reports a decrease in the mean amplitude of almost all deflections during behavioural arousal in the cat.

Taylor, N.A., Evoked Potential Latencies and Psychometric Intelligence, unpublished Master's thesis presented to the Faculty of Psychology and Education of the University of Ottawa, Ontario, 1966, ix-76 p.

This excellent study replicates the original findings of Ertl concerning the relationship between photic evoked response latencies and human psychometric intelligence. The author is also concerned with the "power" and "speed" components of human intelligence.

Walters, G.C., J. Pearl and J.V. Rogers. "The Gerbil as a Subject in Behavioral Research", Psychological Reports, Vol. 12, 1963. p. 315-318.

The authors present some of the characteristics of the Mongolian gerbil and report that in the Skinner box the gerbils excel the rats consistently.

APPENDIX 1

PHOTIC EVOKED POTENTIAL LATENCIES AND AMPLITUDE

APPENDIX 1

PHOTIC EVOKED POTENTIAL LATENCIES[1] AND AMPLITUDE[2]

Subject[3]	E1 Latency	E2 Latency	E3 Latency	Amplitude
FE1	120	251	176	3.16
FE4	109	231	173	4.30
FE7	89	259	154	2.61
FE10	117	250	188	2.88
FE19	85	313	123	3.76
VE2	128	298	186	3.54
VE5	80	177	134	4.59
VE8	79	229	131	5.02
VE11	115	251	165	3.21
VE20	112	277	173	2.25
D3	92	321	143	2.89
D6	91	250	158	3.78
D9	146	366	226	6.51
D12	100	214	166	2.88
D21	85	189	152	3.41

[1] All latency values are expressed in milliseconds.

[2] All amplitude values are expressed in millivolts.

[3] The littermates of FE1 are VE2 and D3; those of FE4, VE5 and D6, etc.

APPENDIX 2

SHUTTLE-BOX LEARNING SCORES

APPENDIX 2

SHUTTLE-BOX LEARNING SCORES

Subject[1]	Score[2]
FE1	16
FE4	15
FE7	10
FE10	10
FE19	11
VE2	49
VE5	12
VE8	71
VE11	10
VE20	13
D3	200
D6	24
D9	200
D12	153
D21	78

[1] The littermates of FE1 are VE2 and D3; those of FE4, VE5 and D6, etc.

[2] The score shown represents the total number of trials required by each subject to reach the criterion performance of nine out of ten avoidance responses in a shuttle-box conditioning task.

APPENDIX 3

EXPLORATION SCORES

APPENDIX 3

EXPLORATION SCORES

Subject[1]	Score[2]
FE1	49
FE4	54
FE7	61
FE10	54
FE19	63
VE2	39
VE5	70
VE8	37
VE11	65
VE20	48
D3	17
D6	30
D9	35
D12	17
D21	23

[1] The littermates of FE1 are VE2 and D3; those of FE4, VE5 and D6, etc.

[2] The score shown represents the total number of units covered during a three-minute period in an exploration box.

APPENDIX 4

EMOTIONALITY SCORES

APPENDIX 4

EMOTIONALITY SCORES

Subject[1]	Score[2]
FE1	18.0
FE4	4.5
FE7	16.0
FE10	6.5
FE19	7.0
VE2	12.0
VE5	6.5
VE8	8.5
VE11	11.5
VE20	6.5
D3	2.0
D6	8.0
D9	2.5
D12	1.0
D21	6.0

[1] The littermates of FE1 are VE2 and D3; those of FE4, VE5 and D6, etc.

[2] The score shown represents the average of the total number of pellets defecated and the total number of squeals emitted during the restraining and *PEP* recording session for each subject.

APPENDIX 5

ACTIVITY SCORES

APPENDIX 5

ACTIVITY SCORES

Subject[1]	Score[2]
FE1	33
FE4	6
FE7	24
FE10	27
FE19	17
VE2	11
VE5	16
VE8	15
VE11	26
VE20	15
D3	3
D6	10
D9	18
D12	6
D21	15

[1] The littermates of FE1 are VE2 and D3; those of FE4, VE5 and D6, etc.

[2] The score shown represents the total number of millimetres indicated on a recorder for each subject in an activity cage.

APPENDIX 6

HEART RATE SCORES

APPENDIX 6

HEART RATE SCORES

Subject[1]	Score[2]
FE1	144
FE4	160
FE7	156
FE10	80
FE19	120
VE2	192
VE5	176
VE8	208
VE11	120
VE20	212
D3	176
D6	216
D9	144
D12	160
D21	188

[1] The littermates of FE1 are VE2 and D3; those of FE4, VE5 and D6, etc.

[2] The score shown represents the total number of heart beats per minute for each subject as recorded on an electrocardiograph.

APPENDIX 7

ABSTRACT OF

The Effects of Early Differential Environments on Photic Evoked Potentials, Arousal and Behaviour of the Mongolian Gerbil

APPENDIX 7

ABSTRACT OF

The Effects of Early Differential Environments on Photic Evoked Potentials, Arousal and Behaviour of the Mongolian Gerbil[1]

The present investigation is an outgrowth of previous human and animal studies conducted at the Department of Psychophysiology of the University of Ottawa. These studies have attempted to examine the relationship between photic evoked potential latencies, possibly reflecting a measure of biological intelligence and intellectual efficiency as measured on conventional instruments.

More recently, a number of studies concerning the effects of early differential exteroceptive stimulation with the albino rat as subject disclosed that rats reared in a deprived environment exhibited significantly longer photic evoked potential latencies and poorer discrimination learning than littermates reared in an enriched environment.

Based on these results and on a number of theoretical viewpoints, the purpose of this investigation was to partially replicate and possibly extend previous findings to the Mongolian gerbil. It was also decided to investigate whether

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[1] R.P. Bourgeois, Master's thesis presented to the Faculty of Psychology of the University of Ottawa, Ontario, 1970, viii-106 p.

additional auditory, olfactory and tactile stimulation has any effect on later adult psychophysiological and behavioural measures.

The subjects thus consisted of a sample of fifteen male Mongolian gerbils which were separated at weaning into three groups, the first two being reared in Fully Enriched and Visually Enriched environments, while the third was reared in a Deprived environment, to the age of three months, when all testing took place.

The first major hypothesis stated that there are no significant differences in the PEP waveforms (latencies and amplitude) of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched and Deprived environments. No significant differences were found and the writer thus cannot reject the first major hypothesis. These results are discussed in terms of the possible relatively detrimental effect of early overstimulation of afferent pathways at an early age.

The second major hypothesis stated that there are no significant differences in the learning ability of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched and Deprived environments. Since significant differences were obtained and in the predicted direction, the writer thus rejects the second major hypothesis. The superior learning ability of the two enriched groups as compared to the deprived group is attributed to the greater perceptual experience gained by the enriched gerbils.

The first minor hypothesis stated that there are no significant differences in the amount of exploration of gerbils reared from weaning to the age of three months in Fully Enriched, Visually Enriched and Deprived environments. Since significant differences were obtained between the three groups, the writer thus rejects the null hypothesis. The observed differences, however, were not in the predicted direction. Added to important qualitative differences in emotionality between the groups, the writer suggests that early differential environments may be producing differences in fear being reflected in lower exploration scores on the part of the deprived animals.

The second, third and fourth minor hypotheses were concerned with the possible effects of differential environments on emotionality, activity and heart rate between the three groups of gerbils at the age of three months.

Since no significant differences resulted, these three hypotheses were therefore not rejected. Added to the fact that no significant PEP amplitude differences were observed, the data do not support the literature advocating the effects of early differential environments on quantitative measures of emotionality and autonomic arousal.