EFFECTS OF DURATION AND TIMING OF EARLY DIFFERENTIAL REARING ON PHOTIC EVOKED POTENTIALS AND BEHAVIOR OF THE ALBINO RAT

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CURRICULUM STUDIORUM

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INTRODUCTION

There is a growing body of evidence that early environment has marked effects on the behavior of the adult organism. Most investigators believe that such effects are probably associated with the functioning of the central nervous system. Several models of brain functioning have been proposed, and findings are generally interpreted in the context of a specific model.

Several studies conducted at the University of Ottawa have demonstrated that rearing young albino rats in differential environments has measurable effects on photic evoked potentials and on black-white discrimination behavior. In the impoverished animals a latency lengthening of the PEP[1] has been observed, accompanied by decreased efficiency in solving a brightness discrimination task. This is in agreement with studies previously conducted at the University of Ottawa showing a significant relationship between PEP latency and human psychometric intelligence. The findings also suggest that the PEP is a reliable tool for the investigation of the functioning of the central nervous system, and may be used as a physiological measure of animal intelligence, at least in exploratory research.

The majority of animal experimental studies, how-

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1 PEP is the abbreviation for photic evoked potentials.

ever, have focused only on the determinant effects of early differential environment. The relationship between duration and timing of environmental enrichment has not been adequately explored. Results of experimental studies involving the duration-timing relationship have both supported and refuted the theoretical implications of the existence of critical periods in development : the notion that early experiences may produce a permanent and non-reversible modification of functions. Furthermore, the PEP has not been incorporated as a physiological measure of animal behavior in the study of critical periods. Therefore, it would be of great interest to observe the effects of duration-timing interaction of environmental enrichment on PEP and other measures of rat behavior as an indication of the existence or non-existence of critical periods. The question can be raised : Are the effects of differential environments greater at certain ages than others during early development ?

The purpose of the present thesis is to test empirically the critical period hypothesis, and in so doing test the practical importance of the PEP as a physiological tool in animal research.

The first chapter presents a review of the literature. It reviews studies related to the concept of critical periods in the first section, and in the following two sections it reviews relevant studies on the PEP. The latter part of the chapter reviews relevant experimental studies on the effects of early enrichment and impoverishment. The chapter ends with a statement of the experimental hypotheses.

The second chapter gives a description of the experimental procedure and the statistical operations by means of which the experimental hypotheses are tested.

The third and final chapter presents the results expressed numerically, and discusses their implications.

CHAPTER I

REVIEW OF THE LITERATURE

The present study is one of a series of experiments conducted at the University of Ottawa. Previous studies have demonstrated that differential early environments have measurable effects on _PEP_ and brightness discrimination in the albino rat. Since it has been demonstrated at the University of Ottawa that a significant relationship exists between human intelligence scores and _PEP_, it is reasonable to assume that early environment exerts a possible influence on the functioning of the animals' brain as measured by _PEP_. Should empirical findings on lower animals be positive, the present series of experiments should lead to the investigation of environmental effects on the intelligence of the human infant measured behaviorally and physiologically.

Within this context, the existence or non-existence of critical periods and the reversibility of environmental effects on the central nervous system needs to be explored. It is both of theoretical and practical interest to investigate the interplay between the duration of differential environments and the specific ages at which such experiments are introduced. This study distinguishes between the duration and the quality of enrichment. It accepts

Hymovitch's[1] or Edwards'[2] definition of the latter, and studies only the interaction between duration and timing of enrichment.

This chapter reviews the literature on critical or sensitive developmental periods[3], the relationships between _PEP_ and behavioral variables, _PEP_ and age, differential environments and behavior, and differential environments and neurophysiology. It ends with statements of hypotheses to be tested experimentally.

1. Critical or Sensitive Developmental Periods.

The concept of critical periods of development proposes that certain stimuli can only exert their full effects on the maturing organism during limited time epochs, and that these same stimuli will exert minimal or no effect if they are introduced too early or too late.

The earliest rationale for the critical period concept was presented in the field of embryology by

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1 B. Hymovitch, "The Effects of Experimental Variations on Problem-Solving in the Rat", _The Journal of Comparative and Physiological Psychology_, Vol. 45, 1952, p. 314.

2 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.

3 The terms 'critical period' and 'sensitive period' will be used interchangeably in this thesis in order to conform to the nomenclatures used by different authors.

Child[4] who found that rapidly growing tissues of an embryo are especially sensitive to environmental stimulation; whereas at later stages when the rate of growth subsided, environmental influences were less marked.

Evidence both for and against the critical period hypothesis, however, has come chiefly from the field of psychology. Psychologists have used behavioral variables such as problem-solving and arousal as their dependent variables in critical period investigations.

Hebb[5] argued that differential early experience is an important determinant of an individual's problem-solving capacity, and suggested that early perceptual learning tends to be permanent and has generalized transfer effects, being nonspecific to particular situations. Thus he supports the critical period hypothesis.

Hebb's theory has received widespread support from studies by Hymovitch[6], Forgays and Forgays[7], Bingham and

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4 C.M. Child, Patterns and Problems of Development, Chicago, University of Chicago Press, 1941.

5 D.O. Hebb, The Organization of Behavior, New York, John Wiley, 1949, p. 296.

6 B. Hymovitch, Op. Cit., p. 313-321.

7 D.G. Forgays and J.W. Forgays, "The Nature of the Effect of Free-Environmental Experience in the Rat", The Journal of Comparative and Physiological Psychology, Vol. 45, 1952, p. 322-328.

Griffiths[8], and others, which will be reviewed in a later section of this chapter.

Thompson and Schaefer[9], in reviewing a series of studies on the effects of early stimulation on the rat's adrenocortical response to stress, have concluded that the earlier the stimulation the greater the effect but only within a time epoch between the first week and sixteen days of life, at which point the animal's adrenal system reaches maturity. Their conclusions support a critical period hypothesis and suggest that within this period there may be a functional relationship between the timing of the stimulation and the intensity of its effects.

More recently, the Hebbian theory has been challenged by Woods[10] who showed that after reversal of environments from impoverished to enriched, mature animals could improve on a variety of tasks, and by Reid _et al._[11] who

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8 W.E. Bingham and W.J. Griffiths, "The Effect of Different Environments During Infancy on Adult Behavior in the Rat", _The Journal of Comparative and Physiological Psychology_, Vol. 45, 1952, p. 307-312.

9 W.R. Thompson and T. Schaefer, in _Function of Varied Experience_, D.W. Fiske and S.R. Maddi,Ed., Dorsey, Homewood, 1961, p. 81-105.

10 P.J. Woods, "The Effects of Free and Restricted Environmental Experience on Problem-Solving Behavior in the Rat", _The Journal of Comparative and Physiological Psychology_, Vol. 52, 1959, p. 399-402.

11 L.D. Reid, J.H. Gill and P.B. Porter, "Isolated Rearing and Hebb Williams Maze Performance", _Psychological Reports_, Vol. 22, No. 3, 1968, p. 1073-1077.

attributed the effects of isolation not to an impairment of intellectual capacity, but to motivational interference with the learning process. The writer interprets such motivational effects as reversible. The specific findings of these two studies will be discussed in a later section.

Physiologists and biochemists who oppose the hypothesis of a critical period are exemplified by the California group of researchers headed by Krech, Rosenzweig, and Bennett. In a 1964 study[12], these investigators failed to identify a time epoch in the rat's life which was most sensitive to environmental enrichment, using brain enzymes and brain weight as criterion variables. The specific findings of this and other studies by this group of investigators will be discussed in a later section of this chapter.

Major opposition to the critical period hypothesis comes from the Purdue group of researchers headed by Denenberg and Whimbey, who have conducted a series of studies on experimental programming of the rat's life history, using complex factorial designs involving various age groups, various types of stimulation, and various behavioral measures. A number of their studies, as shown by Denenberg and Karas[13],

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12 M.R. Rosenzweig, E.L. Bennett and D. Krech,"Cerebral effects of environmental Complexity and Training among Adult Rats", The Journal of Comparative and Physiological Psychology, Vol. 57, 1964, p. 438-439.

13 V.H. Denenberg and G.G. Karas, "Interactive Effects of Age and Duration on Infantile Experience on Adult Learning", Psychological Reports, Vol. 7, 1960,p. 313-322.

have found that upon reversal of environment, restricted animals showed measurable improvement, thus disagreeing with the critical period hypothesis that there are certain time epochs in infancy beyond which a particular class of stimuli fails to have measurable effects on subsequent behavior. In 1964, Denenberg[14] argued that where findings have been consistent with the critical period hypothesis, further studies have been able to show that it is a complex function. He proposed that the amount of stimulus input in infancy acts to reduce emotional and intellectual reactivity in a monotonic fashion. Thus, the relationship between the amount of stimulation and later performance on tasks of moderate difficulty is U-shaped. In conclusion, Denenberg suggested that there are probably different critical periods depending on the intensity and type of stimulation and the kind of behavior measured later. He also pointed out that there are probably optimal levels of stimulation for specific behaviours, so that very strong or very weak stimulation tends to be detrimental to later behavior. Based on the above, the writer interprets Denenberg's position as not incompatible with the existence of critical periods, though opposed to any simplistic descriptions of such periods.

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14 V.H. Denenberg, "Critical Periods, Stimulus Input, and Emotional Reactivity : A Theory of Infantile Stimulation", Psychological Review, Vol. 71, No. 5, 1964, p. 335-351.

Such conflicting findings as discussed above led Scott[15] to believe that there are perhaps two critical periods, one based on a physiological process such as the development of the adrenocortical stress mechanism, extending to 16 days of age in the rat; the other based on a psychological process such as the reduction of emotional reactivity, beginning at 17 days when the eyes first open and extending to 30 days.

In concluding this section, the writer wishes to point out that evidences both for and against critical periods have not been fully reconciled to date in the experimental literature. The subject bears further investigation. The concept of critical period is especially rich in its implications if it can be broadly defined. However, the cautions of Denenberg and Scott must be taken into account. For this reason, the present investigation will employ both physiological and behavioral measures in attempting to establish the existence of critical periods in relation to early environmental enrichment.

2. Evoked Potentials and Behavior.

The purpose of this section is to review studies which deal with possible relationships between evoked

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15 J.P. Scott, "Critical Periods in Behavioral Development", <u>Science</u>, Vol. 138, 1962, p. 949-958.

potentials and psychological variables, specifically intelligence, attention and arousal.

a. Evoked Potentials and Intelligence.

Several studies have been conducted at the University of Ottawa to explore the relationship between evoked potentials and human intelligence. In the first of these, Ertl[16] obtained a significant correlation of -.88 between PEP latency expressed as intracortical delay and intelligence scores on a sample of 11 students. However, this initial finding has been criticized by Edwards[17] on the grounds of small sample and crude instrumentation.

In 1965, Chalke and Ertl[18], using a special technique for the measurement of evoked potentials described as the zero crossing technique[19], studied 48 subjects, divided into groups of high, average, and low intelligence. The

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16 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, 1961, viii-41 p.

17 H.P. Edwards, "Effects of Early Rearing in Differential Environments on the Albino Rat's Photic Evoked Potentials, Unpublished Doctoral Thesis presented to the Faculty of Psychology of the University of Ottawa, Ontario, 1967, viii-73 p.

18 F.R. Chalke and J.P. Ertl, "Evoked Potentials and Intelligence", Life Sciences, Vol. 4, 1965, p. 1319-1322.

19 J.P. Ertl, "Detection of Evoked Potentials by Zero Crossing Analysis", EEG and Clinical Neurophysiology, Vol. 18, 1965, p. 630-631.

authors found significant negative correlations between intelligence scores and latencies of later components from 200 msec. on, particularly the third and fourth components. Furthermore, significant differences were found in comparisons of the evoked responses for the three experimental groups with respect to mean latencies of the third, fourth, and fifth components. The authors therefore hypothesized that the latency of evoked responses is a measure of the efficiency of the organism in processing information.

In a subsequent study, Ertl[20] used three psychometric measures of intelligence, the Otis Quick-Scoring Test of Mental Ability, the Primary Mental Abilities, and the WISC, on 300 children. Most of the correlations between the various wave components of the evoked potentials and intelligence test scores were found to be highly significant (p= .001) although most coefficients were below .40. The results were interpreted as supporting the hypothesis stated earlier that the latency of evoked potentials is related to neural efficiency. However, the statements made by Ertl that neural efficiency can be operationally defined as the information processing time measured by the averaged evoked potentials latency should be accepted with caution, since the size of the correlations obtained in

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20 J.P. Ertl, "Neural Efficiency and Human Intelligence", Journal of Educational Research,

this study leaves a large proportion of the total variance still unaccounted for.

Recent findings by Rhodes _et al._[21] lend support to the hypothesis that averaged evoked potentials reflect higher mental processes. They investigated _PEP_ recordings on 20 bright (_WISC_ full scale mean = 130) and 20 dull (_WISC_ full scale mean = 79) children. They found that when bright children were compared with the dull children, the bright children had significantly larger amplitudes in late components of parietal and occipital _PEP_ recordings, and the late components of bright children were more homogeneous than those of dull children. Furthermore, dull children did not demonstrate hemispheric assymetry in amplitude, whereas _PEP_ amplitudes of bright children were larger over the right hemisphere. There were, however, no significant differences in latency between the bright and the dull groups, which is not consistent with Ertl's findings. It is interesting to note that the investigators reported that the difference in amplitudes did not appear to be a function of maturational process, since all subjects were about the same age. Findings were also consistent at several stimulus intensities. However, there were some inconsistencies in the data. In the comparison of bright vs dull children, the amplitude differential

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21 L.E. Rhodes, R.E. Dustman and E.C. Beck, "The Visual Evoked Response : A Comparison of Bright and Dull Children", _EEG and Clinical Neurophysiology_, Vol.27, 1969, p.364-372.

was not always in favor of the bright children across all the components studied. The results suggest that amplitude as well as latency of the PEP should be investigated.

It appears to the writer that, in general, the weight of evidence suggests that latency of PEP, being more stable than amplitude, is more likely to be related with intelligence which is also considered to be quite stable over time; and the amplitude of PEP, which is less stable, is more likely to be related with fluctuating states of attention or arousal.

b. Evoked Potentials and Attention.

A number of studies have been directed at explicating the relationship between averaged evoked potentials and attention.

Studies on the habituation effect of repetition of trials on PEP have shown that, with progressing habituation, the amplitude of the evoked response would decrease and eventually disappear. This diminution and final disappearence of the visual response to outside stimulation suggests that "central" mechanisms may in some way control the sensory input to the brain.

Closely related to habituation is the phenomenon of attention. Attention involves the selective passage of relevant sensory information to consciousness with simultaneous exclusion of insignificant signals. Electrophysiologically this phenomenon refers to a reduction or disappearance of evoked responses to one stimulus while the organism reorients its attention to a novel stimulus. For example, Hernandez-Peon et al.[22] reported that the cat's evoked responses to click stimuli disappeared during the presentation of visual, olfactory or tactile stimuli.

Studies on reaction time by Donchin and Lindsley[23], Morrell and Morrell[24] suggest a non-zero relationship between averaged evoked potential components and reaction time. However, the findings differed in attributing the primary relationship to either latency, or amplitude, or both. The general conclusion of these studies, nevertheless, is that evoked potential components reflect the effects of the non-specific reticular activating system on cortical excitability. It is suggested that reaction time delay is an inverse function of cortical excitability : the shorter the reaction time, the greater the cortical excitability. Support for

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22 R. Hernandez-Peon, H. Scherrer and M. Jouvet, "Modification of Electric Activity in Cochlear Nucleus During 'Attention' in Unanesthesized Cats", Science, Vol. 123, 1956, p. 331-332.

23 E. Donchin and D.B. Lindsley, "Averaged Evoked Potentials and Reaction Times to Visual Stimuli", EEG and Clinical Neurophysiology, Vol. 20, 1966, p. 217-223.

24 L.K. Morrell and F. Morrell, "Evoked Potentials and Reaction Times : A Study of Intra-individual Variability", EEG and Clinical Neurophysiology, Vol. 20, 1966, p. 567-575.

this notion has been given by various investigators who suggest that evoked potentials reflect attentiveness and alertness of the subject. The reader is referred to studies by Haider et al.[25]; Garcia-Austt et al.[26]; and Spong et al.[27]

The amplitude of the evoked potentials has been used as dependent variable in many studies. Abraham and Marsh[28] found that the rate of presentation of stimuli affected the amplitude, and that cortical evoked potentials were reduced when the auditory stimuli were presented faster. For rates slower than one p er sec. the amplitude of the evoked potentials in the cortex was greater than the amplitude in the cochlear nucleus, while for rates faster than one per sec. the reverse was the case; probably suggesting that some cortical process amplifies or inhibits the evoked response.

Although Thompson and Spencer[29] held a negative

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25 M. Haider, P. Spong and D.B. Lindsley, "Attention, Vigilance, and Cortical Evoked-Potentials in Humans", Science, Vol. 145, 1964, p. 180-182.

26 E. Garcia-Austt, J. Bogacz and A. Vanzulli, "Effects of Attention upon Visual Evoked Response", EEG and Clinical Neurophysiology, Vol. 17, 1964, p. 136-143.

27 P. Spong, M. Haider and D.B. Lindsley, "Selective Attentiveness and Cortical Evoked Responses to Visual and Auditory Stimuli", Science, Vol. 148, 1965, p. 395-397.

28 F.D. Abraham and J.T. Marsh, "Amplitude of Evoked Potentials as a function of Slow Presenting Rates of Repetitive Auditory Stimulation", Experimental Neurology, Vol.14, 1966, p. 187-198.

29 R.F. Thompson and W.A. Spencer, "Habituation", Psychological Review, Vol. 73, 1966, p. 16-43.

view on the evidence reviewed by them relating to the habituation of the evoked potential, there is sufficient evidence in the literature to support the view that changes in the amplitude of the cortical evoked potential may occur with repetitive stimulation.

White and Eason[30] reported a series of studies on the occipital evoked potential produced by light without contours. They commented that habituation, characterized by the diminution of the size of the amplitude and elongation of the latency of the evoked potentials, was undoubtedly related to subjective factors operating in the organism such as attention, vigilance, level of activation, and cognition of the meaningfulness of the stimuli.

In a publication by Ertl[31], changes in the amplitude of evoked potentials under different conditions were described as simply changes in the synchrony of the evoked potentials to repetitive stimulation. An increase in amplitude could be attributed to more synchrony and less variability, while a decrease in amplitude was attributable to

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30 C.T. White and R.G. Eason, "Evoked Cortical Potentials in Relation to Certain Aspects of Visual Perception", Psychological Monographs, Vol. 80, 1966, 24 p.

31 J.P. Ertl, "Evoked Potential Recovery From Tape Recorded Zero Crossings of the EEG", EEG and Clinical Neurophysiology, Vol. 22, 1967, p. 387-388.

less synchrony and more variability. This change in amplitude was in no way described as related to changes in latency.

In the light of these findings, studies on the relationship between intelligence and evoked potentials can be interpreted in a different way from Ertl's neural efficiency hypothesis. Attention, being an aspect of cognition, may confound intelligence test scores. As described in the previous section, it has been found that both latency and amplitude measurements of evoked potentials are related to intelligence scores. These seemingly conflicting findings may be exp lained by the fact that attention affects both intelligence scores and averaged evoked potentials. Subjects who attend better may score higher on paper intelligence tests and have a more stable evoked response than less attentive subjects. Thus, when the evoked responses are averaged or summed over trials, there results a recruitment for subjects having stable wave forms giving rise to larger amplitudes; and a damping for subjects having unstable wave forms resulting in smaller amplitudes. It is therefore possible that latency measurements of <u>PEP</u> may be used as an index of neural efficiency, as proposed by Ertl; and amplitude measurements of <u>PEP</u>, found to be related to test intelligence by Rhodes <u>et al</u>., may be used as an index of cortical excitability or attention, or even arousal, which will be discussed in the next section.

c. Evoked Potentials and Arousal.

The effect of arousal on evoked potentials has been studied by Schwartz and Shagass[32]. Using a sample of cats, they found that amplitude of somatosensory potentials decreased with increasing state of arousal. However, when auditory potentials were used, the amplitudes increased in some animals and decreased in others during high arousal states, so that results were on the whole inconclusive.

In 1963, Frommer and Livingston[33] studied the responses from somatosensory cortex evoked by bulbar-trigeminal stimulation in different states of arousal. Their data demonstrated that under states of arousal based on behavioral and EEG criteria characteristics, evoked responses generated by activating a nonsensory central system decreased in amplitude and duration. The reverse was also found to be true : amplitude and duration increased with signs of reduced arousal. In contrast, the response from the motor area evoked by cerebellar stimulation, which in the waking

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32 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. 11-20.

33 G.P. Frommer and R.B. Livingston, "Arousal Effects on Evoked Activity in a 'Nonsensory' System", Science, Vol. 139, 1963, p. 502-504.

cat consisted of a short latency biphasic component followed by slower waves, was attenuated or abolished completely under states of decreased arousal. It appears that evoked responses, using inplanted electrodes in a 'nonsensory' system, are either enhanced or reduced in a state of arousal, depending on the area of the brain from which the responses are recorded.

In general, most investigators report that under their experimental conditions evoked responses in sensory systems usually become larger in amplitude and duration in association with behavioral or EEG signs of reduced arousal. However, it has not always been possible to separate the effects of arousal from other variables such as attention.

3. Photic Evoked Potentials and Age.

Studies on the ontogenesis of PEP in the brain are relevant to this study because they may reflect concurrent structural and biochemical changes during maturation which are correlated with behavioral development.

The development of PEP has been studied in the human by Dustman and Beck[34], in the cat by Rose and Lindsley[35],

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34 R.E. Dustman and E.C. Beck, "The Effects of Maturation and Aging on the Wave Form of Visually Evoked Potentials", Developmental Psychobiology, Vol. 1, No. 1, 1968, p. 35-40.

and in the dog by Fox[36]. These studies indicate that there is a definite sequence of maturational changes in the PEP wave form particularly when lightly aneathetized animals are used.

In 1968, Rose[37] studied the development of PEP in 35 lightly anesthetized albino rats of the Sprague-Dawley strain between birth and 35 days of age. A definite sequence of wave form changes was found to occur during maturation. The initial response consisted of a long latency, negative deflection at 10 to 11 days of age. At approximately 12 to 13 days of age, a shorter latency of positive-negative-negative complex appeared. With continuing maturation the two negative waves coalesced, and the positive wave became dominant. In other words, the initial long latency negative wave decreased rapidly in latency, and at about 15 days of age, it coalesced with the negative component of the shorter latency positive-negative complex, resulting in a biphasic positive-negative wave similar to that recorded in the adult rat by

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35 G.H. Rose and D.B. Lindsley, "The Differentiation of Visually Evoked Cortical Response Components in Kittens", EEG and Clinical Neurophysiology, Vol. 21, 1966, p. 404.

36 M.W. Fox, "Neuronal Development and Ontogeny of Evoked Potentials in Auditory and Visual Cortex of the Dog", EEG and Clinical Neurophysiology, Vol. 24, 1968, p. 213-226.

37 G.H. Rose, "The Development of Visually Evoked Electrocortical Responses in the Rat", Developmental Psychobiology, Vol. 1, No. 1, 1968, p. 35-40.

Kimura[38]. A second observation was that the onset of evoked electrocortical activity to light flash was related to the onset of myelinization of the optic neuronal pathways which was first apparent at about 12 days old, and to the maturation of the cortical neuroblast which was shown to acquire dendrites and axons at about 10 days of age.

4. Differential Environment and Behavior.

This section will review studies concerning the effects of early differential environments on later behavior. The behavioral variables studied are : problem-solving ability, avoidance learning, motor activity, emotionality and arousal.

a. Problem-solving Ability.

The earliest work in this area was performed by Hebb[39] in 1947. He found that rats raised in laboratory cages, when compared with rats reared as pets, were inferior problem solvers. He used a special method of rating animal intelligence, known as the Hebb-Williams' Test of Animal

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38 D. Kimura, "Multiple Response of the Visual Cortex of the Rat to Photic Stimulation", EEG and Clinical Neurophysiology, Vol. 14, 1962, p. 115-122.

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

Intelligence[40].

Hebb's research triggered enormous interest in the environmental effects on animals. The bulk of research findings suggest strongly that impoverished animals are inferior in tests of animal intelligence to enriched animals.

In 1952, Hymovitch[41] reared enriched rats in the 'free-environment' box, which consisted of a large cage with runways and playthings, and impoverished rats in small cages or enclosed activity wheels. He found that the former were superior problem-solvers and less emotional. A second finding was that the behavior patterns of impoverished animals when switched to the enriched condition were irreversible after 30 to 75 days of age. He found that the sensitive period of development was somewhere between 30 and 75 days of age, in contrast to the general view that the critical period in the rat is probably earlier. The author made the observation that enriched rats made more use of extra-maze cues during problem-solving testing than impoverished rats. Owing to their roomier environment, enriched subjects had a better opportunity to attend to perceptual stimuli which might have transferred either positively or negatively to a

40 D.O. Hebb and K. Williams, "A Method of Rating Animal Intelligence", The Journal of General Psychology, Vol. 34, 1946, p. 59-65.

41 Hymovitch, Op. Cit., p. 313-321.

problem-solving situation depending on the relevancy of the extra-maze cues. He argued that neither motivational nor specific transfer effects could have accounted for the superiority of the enriched subjects; and concluded, following Hebb, that superiority of the enriched subjects was a result of perceptual development that improved their problem-solving.

Bingham and Griffiths[42] compared enriched and deprived rats on a maze-solving ability, emotionality defined as susceptibility to sound induced seizures, and Lashley jumping stand for brightness discrimination. A significant difference was found in maze-solving ability, but not in brightness discrimination or emotionality.

In a related study, Thompson and Heron[43] studied the effects of early environment in 26 Scottish terriers divided into four groups : a control group reared as pets, and three experimental groups of isolated, restricted, and slightly restricted dogs. Through the use of orientation, barrier delayed reaction and open-field maze tests as measures of animal intelligence, significant differences were found between the control group and the experimental groups, interpreted as support for the hypothesis that early restriction impaired perceptual organisation. The authors

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42 Bingham and Griffiths, Op. Cit., p. 307-312.

43 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, 1954, p. 17-31.

reported no significant differences in motivation or emotionality between the control and experimental groups. These were considered as confounding variables that might bias the performance on learning ability.

Forgays and Forgays[44] have shown that rats which were reared in small cages but without perceptual restriction made less errors on the Hebb-Williams' closed field test than rats reared in large cages with perceptual restriction. From this, it appears that perceptual restriction has exerted greater effect than spatial restriction.

In 1954, Forgus[45] reared hooded rats under three conditions. One group was reared in a complex visual proprioceptive environment; a second group in a visual environment but with no opportunity for proprioceptive experience; a third group in a homogeneous visual-proprioceptive environment. Results showed that early experience was effective in determining the emotional and cognitive ability of rats reaching maturity later. The author further suggested that the quality of the animal's early experience may determine the kinds and number of mental 'hypotheses' to be tested when solving a problem at adulthood.

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44 Forgays and Forgays, Op. Cit., p. 322-328.

45 R.H. Forgus, "The Effect of Early Perceptual Learning on the Behavioral Organization of Adult Rats", The ~~Vol.~~ Journal of Comparative and Physiological Psychology, Vol. 47, 1954, p. 331-336.

Woods[46] found that rats reared in a restricted environment to the age of sixty days and subsequently enriched showed some improvement, but still were inferior problem-solvers than control animals reared in an enriched environment throughout the study, thus suggesting that the effect of early impoverishment was not quite permanent.

A recent extension of the work on the effects of early differential environment was published by Denenberg *et al*.[47] in 1968. The authors reared 38 rats from birth to 21 days of age, half of which in laboratory cages and half in enriched free environment. From 21 days to 50 days, half of each group were further reared in laboratory cages and half in free environment. Then all animals were kept in laboratory cages until 371 days when testing began. It was found that both preweaning and postweaning enriched animals performed better in the Hebb-Williams problem-solving test.

Another recent study was conducted by Brown[48] in 1968. The author investigated rats reared in a complex

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46 Woods, *Op. Cit*., p. 399-402.

47 V.H. Denenberg, J.M. Woodcock and K.M. Rosenberg, "Long-Term Effects of Preweaning and Postweaning Free-Environment Experience on Rat's Problem-Solving Behavior", *The Journal of Comparative and Physiological Psychology*, Vol. 66, No. 2, 1968, p. 533-535.

48 R.T. Brown, "Early Experience and Problem-Solving Ability", *Journal of Comparative and Physiological Psychology*, Vol. 65, 1968, p. 433-440.

environment, restricted environment, simple environment, and an environment with barriers, on exploration tests, stationary Hebb-Williams closed field test, and the same closed field test rotated after each trial. He found that, in the closed field test, the complex, simple, and environment with barriers animals were superior to restricted animals only under the stationary condition, and there were no significant differences in exploratory behavior. The author ascribed superior Hebb-Williams test performance by the animals enriched to various degrees to greater use of extrafield cues or cues outside the test situation by these subjects than by the restricted subjects. This interpretation is compatible with Hymovitch.[49]

Negative findings on the superiority in problem-solving abilities in enriched animals over impoverished animals were provided by Reid et al.[50] They found that male hooded rats reared in isolation were more emotional, but contrary to previous reports, they were as efficient at solving maze problems as subjects reared together in large cages containing various objects. The authors conclude that problem-solving efficiency of the two groups was equalized by reducing the effect of emotionality, such as, by

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49 Hymovitch, Op. Cit., p. 313-321.

50 Reid, Gill and Porter, Op. Cit., p. 1073-1077.

harsh deprivation for the food incentive, by greater pre-training habituation, and by reducing the possibility for direct positive transfer from the training and experiences of enrichment to maze-solving. The authors therefore favor a hypothesis that early rearing affects motivational factors rather than the capacity to solve problems.

Although in this section the writer has reviewed only typical studies, he wishes to conclude by noting that upon exhaustive ~~reviews~~ review of studies in this area the weight of evidence supports by a slight margin the hypothesis that differential rearing affects primarily the problem-solving efficiency as a direct outcome and not simply as a byproduct of motivational or arousal differences.

b. Avoidance Conditioning.

Several studies have reported that early life experiences significantly influence avoidance learning at maturity, although there are discrepancies in the data which may be attributable to genetic or procedural differences. The specific findings of these studies are not relevant to the principal aims of this study, but they are included because avoidance conditioning will be used as a behavioral test by the writer.

In 1963, Levine and Broadhurst[51] reported that

51 E. Levine and P.L. Broadhurst, "Genetic and Ontogenic Determinants of Adult Behavior in the Rat", Journal of Comparative and Physiological Psychology, Vol. 56, 1963, p. 423-428

infantile stimulation significantly affected emotionality and avoidance learning in different Maudsley strains of rat, with the greatest effect on the reactive strain.

In a related study, Powell and Leach[52] investigated the effects of enriched, neutral, and impoverished environments on the subsequent emotionality and avoidance performance of female rats from the Tryon S1 and S3 strains of rat. The animals were subjected at weaning to the differential environments for 50 days and tested for open field emotionality and avoidance learning using a modified Miller-Mowrer box. The authors found strain differences for both emotionality and avoidance learning, but no significant effect of environment on either measures, the S3 strain being less emotional and better performers in avoidance learning than the S1 strain. The results suggest that postweaning environmental experiences were not effective in altering strain differences in emotionality and avoidance performance.

In order to determine whether the observed effects on avoidance behavior were the result of early as distinguished from previous experience, Ader and Schaefer[53]

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52 B.J. Powell and M. Leach, "Effects of Environmental Complexity on Emotionality and Avoidance Performance of Tryon S1 and S3 Strains", Psychonomic Science, Vol. 9, No. 5, 1967, p. 287-288.

53 R. Ader and A. Schaefer, "Effects of Early Experiences on One-Trial Avoidance Conditioning", Psychonomic Science, Vol. 10, No. 7, 1968, p. 235-236.

investigated the effects of handling and electric shock stimulation experienced before and after weaning on the extinction of avoidance response conditioned in one trial. Female rats of the Charles River strain were either handled, shocked or unmanipulated during pre- and post-weaning period. It was found that under the regular one-sec. shock procedure, response latencies were influenced by previous shocking (one shock per sec.) experience, with animals shocked during the postweaning period showing the longest latencies. Under the variable shock procedure, however, it was found that all previously manipulated groups showed longer latencies than controls. In other words, the resistance to extinction of an avoidance response conditioned in a single trial was greater in both handled and shocked animals when compared with unmanipulated controls. The authors attributed the observed differences to previous rather than to early non-specific experiences.

c. Exploration and Activity.

One of the early studies on activity of impoverished animals was performed by Thompson and Heron[54]. The authors compared 12 Scottish terriers restricted with varying severity for the first 7 to 10 months of life and 8 littermates reared

54 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. 77-82.

as pets on two experiments involving situations of varying complexity. The results indicate that impoverished animals explored significantly more than controls, and the more severe the restriction, the greater the exploration.

In a later study, Zimbardo and Montgomery[55] suggest that the inferiority of impoverished animals in problem-solving, such as the Hebb-Williams maze performance may have resulted from greater exploration by the restricted animals than enriched ones. They found that impoverished animals tend to explore more than enriched rats in a novel test situation. This greater exploration increased their error scores. This interpretation disagrees with the Hebbian theory[56] that the superiority of enriched animals in problem-solving is attributable to the acquisition of complex neural organisations through varied early experience; and agrees with the hypothesis of Reid _et al_.[57] that the effect of early environment is motivational.

In 1967, Sackett[58] studied motor activity and exploration

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55 P.J. Zimbardo and K.C. Montgomery, "Effects of 'Free-Environment' Rearing upon Exploratory Behavior", _Psychological Reports_, Vol. 3, 1957, p. 589-594.

56 Hebb, _Op. Cit._, p. 306-307.

57 Reid, Gill and Porter, _Op. Cit._, p. 1073-1077.

58 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, 1967 p. 369-375.

involving black, white, and patterned stimuli in the testing situation in rats. The animals were reared with varying degrees of deprivation in darkness, alternating light-dark, and patterned cages. It was found that motor activity was higher with increased deprivation, and that exploration was greatest with the moderately deprived group. A second finding was that the effects of rearing conditions on motor activity were persistent, while the same effects on exploratory behavior were reversible.

In agreement with the above, Essman[59] studied the effects of isolation and aggregation of male CF-1 mice from weaning at 21 days until 45 days of age, at which time, the subjects were tested and sacrificed for brain-serotonin analysis. It was found that isolated animals showed higher levels of motor activity, higher brain-serotonin levels, increased rate of brain-serotonin turnover with a lower brain-serotonin turnover time, when compared with littermates housed under aggregated conditions. The authors suggested that the differences in activity was related to the altered pattern of brain-serotonin metabolism.

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59 W.B. 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. 244-246.

d. Emotionality and Arousal.

In 1956, Thompson et al.[60] studied the 'whirling' behavior of dogs reared in isolation from one to ten months of age. 'Whirling' was described as rapid, jerky running in a tight circle; shrill agonized yelping, barking and snarling; tail snapping and tail biting. Such behavior was triggered off by changes in the stimulus environment, and the animals were unable to control their behavior. In addition, the isolated dogs when compared with their littermates reared as pets at homes were found to differ significantly in 'all' phases of behavior, including intelligence, activity, emotionality, and social behavior. The authors suggested a possible relationship between restriction in early life and such behavior.

Becker and Flaherty[61], in 1966, studied the effects of handling on rats. The authors found that handled rats were less timid,based on short cage-emergence latency; less fearful,based on absence of reluctance to eat; and socially dominant,based on winning food competition with controls.

Denenberg in 1964 hypothesied that "Emotional

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60 W.R. Thompson, R. Melzack and T.H. Scott,'"Whirling Behavior' in Dogs as Related to Early Experience", Science, Vol. 123, 1956, p. 939.

61 G. Becker and T.B. Flaherty, "Effects of Postweaning Tactile Stimulation on Emotionality and Social Dominance in the Rat", Psychological Reports, Vol. 19, 1966, p. 363-366.

reactivity is reduced as a monotonic function of amount of stimulus input in infancy"[62] Since then, he and his associates have performed a series of studies concerning his monotonicity hypothesis of infantile stimulation and emotional reactivity. Stimulus input has been varied in several ways, including the number of days of handling, number of days of shock, and form of stimulation. Emotional reactivity has been measured by diverse procedures including open-field performance, consummatory behavior, timidity tests, and performance prior to and during avoidance learning. The weight of evidence suggests that animals who received more infantile stimulation were significantly less emotional. A typical Denenberg and Haltmeyer[63] study is reviewed here, which used a physiological measure to assess emotional reactivity. It has previously been found that the amount of corticosterone released by the adrenal cortex was related to emotional reactivity in such a way that less emotional animals had a significantly smaller corticosterone response. The authors handled 80 Purdue-Wistar rats for 0, 5, 10, or 20 days. Immediately following the period of handling, the subjects were placed for ten minutes in a novel environment,

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62 Denenberg, Op. Cit. p. 338.

63 V.H. Denenberg and G.C. Haltmeyer, "Test of the Monotonicity Hypothesis Concerning Infantile Stimulation and Emotional Reactivity", Journal of Comparative and Physiological Psychology, Vol. 63, No. 3, 1967, p. 394-396.

during which time half the group received shock while the other half was not stimulated. The subjects were decapitated immediately following this procedure, and their blood was analysed for corticosterone content. A significant linear decrease in plasma corticosterone was found as a function of number of days of handling, thus supporting the monotonicity hypothesis.

A related study was recently conducted by Ader[64]. The author studied the effects of preweaning and postweaning handling on rats. At three months old, the subjects were tested on reaction-to-handling tests and their corticosterone levels were determined. The results showed that behavioral emotionality of handled rats during the preweaning period was significantly less than controls. However, there was no consistency in the behavioral data of subjects manipulated after weaning, and the data provided no evidence of a relationship between emotional reactivity and plasma corticosterone.

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64 R. Ader, "Effects of Early Experiences on Emotional and Physiological Reactivity in the Rat", Journal of Comparative and Physiological Psychology, Vol. 66, No. 2, 1968, p. 264-268.

5. Differential Environment and Neurophysiology

In the previous section studies that deal with a variety of behavioral differences as well as differences in plasma serotonin metabolites as a result of differential rearing have been discussed. This section will review studies designed to determine the extent to which differential rearing would lead to differences in brain chemistry, brain activities such as the EEG and PEP. Owing to employment of different instruments and emphasis on one aspect of environment : enrichment or impoverishment, the studies are reviewed under the following headings :- Enrichment studies; Impoverishment studies; and Studies contrasting the effects of enrichment and impoverishment.

a. Enrichment Studies.

This section will review studies published by the California group of investigators headed by Krech, Rosenzweig and Bennett. Studies prior to 1965 by this group of researchers have been reviewed extensively by Edwards[65] and will not be exhaustively reviewed here. The reader is also referred to a recent publication by Rosenzweig and Leiman[66] which contains a thorough but concise review of literature

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65 Edwards, Op. Cit., p. 16-20.

66 M.R. Rosenzweig and A.L. Leiman, "Brain Functions", Annual Review of Psychology, Vol. 19, 1968, p. 55-98.

on the topic, and to a paper [67] given at a symposium at the University of California Medical School.

In most of their early experiments, the California group of investigators maintained rats in experimental conditions from weaning to young adulthood (about 105 days). The rats were then sacrificed, their brains removed and subdivided into four cortical areas and one or two subcortical regions. Cholinesterase activity, brain weight and length, number of cortical neurons and glial cells, histological measurements of nuclei and perikarya have been employed as dependent variables, on the hypothesis that exposing rats to complex environment and training would affect these variables.

It has been repeatedly shown[68,69,70] that the

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67 E.L. Bennett and M.R. Rosenzweig, "Potentials of an Intellectually Enriched Environment", Paper given at Symposium 'Dysnutrition in the Seven Ages of Man' at the University of California Medical School, San Fransisco, on Jan. 12, 1969, 25 p. (Personal Communications)

68 E.L. Bennett, M.C. Diamond, D. Krech and M.R. Rosenzweig, "Chemical and Anatomical Plasticity of Brain", Science, Vol. 146, 1964, p. 610-619.

69 D. Krech, M.R. Rosenzweig and E.L. Bennett, "Environmental Impoverishment, Social Isolation, and Changes in Brain Chemistry and Anatomy", Physiology and Behaviour, Vol. 1, 1966, p. 99-104.

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

cholinesterase level in the brain of the enriched animals was higher than their isolated littermates, and the former exhibited heavier cortical weights. Since the subcortex was found to be slightly lighter in enriched subjects, the cortical/subcortical weight ratio gave a slightly more significant difference between the enriched group and the impoverished group acting as controls; this ratio was also found to be more reliable than cortical weight alone.

This group of researchers also reported[71] that of all the cortical areas examined, the occipital cortex showed the largest differences when comparing enriched and isolated groups.

In a 1964 study[72], the findings appear to oppose the concept of critical periods early in the life of rats when differential environment would be most influential, since animals assigned at 105 days of age to the experimental conditions showed as large effects, in terms of brain weight and cholinesterase activity, as did rats assigned at weaning.

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71 E.L. Bennett, D. Krech and M.R. Rosenzweig, "Reliability and Regional Specificity of Cerebral Effects of Environmental Complexity and Training", Journal of Comparative and Physiological Psychology, Vol. 57, 1964, p. 440-441.

72 Rosenzweig, Bennett and Krech, Op. Cit., p. 438-439.

Although the early studies measured the wet brain weight, a recent study[73] has shown that essentially identical results were also found when dry weight of the brain tissues was used. In other words, the 'heavier' brain of the enriched littermate did not just reflect 'water' in the brain.

Several studies[74,75,76] have shown that enriched environment is related to increased cortical depth, increased number of cortical glial cells, while the number of neurons remains the same.

A recent study[77] has shown that the enzymatic cholinesterase changes may be related to possible synaptic modifications rather than to chemical encoding of memory. In addition, enriched rats showed fluctuating cerebral

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73 E.L. Bennett, M.R. Rosenzweig and M.C. Diamond, "Rat Brain : Effects of Environmental Enrichment on Wet and Dry Weights", Science, Vol. 163, 1968, p. 825-826.

74 M.C. Diamond, D. Krech, M.R. Rosenzweig, "The Effects of An Enriched Environment on the Histology of the Rat Cerebral Cortex", Journal of Comparative Neurology, Vol. 123, 1964, p. 111-119.

75 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", Journal of Comparative Neurology, Vol. 128, 1966, p. 117-125.

76 M.C. Diamond, "Extensive Cortical Depth Measurements and Neuron Size Increases in the Cortex of Environmentally Enriched Rats", Journal of Comparative Neurology, Vol. 131, 1967, p. 357-364.

77 M.R. Rosenzweig, E.L. Bennett and M.C. Diamond,

changes during training, which the authors hypothesized to reflect the active processes of memory storage of nucleic acids or proteins. This finding further supports the view that the net differences between enriched and impoverished animals were due to histological changes rather than to transitory memory processes. A third finding of the study indicates that the increase in brain weight and cerebral enzymatic activities was maximal with about 30 days of enrichment, and declined with further enrichment. This appears to support Denenberg's monotonicity hypothesis[78].

At least one study by this group of authors[79] has shown that when enriched (complex environment), neutral (colony), and impoverish~~ment~~-ed (isolated small laboratory cages) were compared with each other, the greatest differrence was between the enriched group and other two groups. Thus, enrichment appears to be a more effective factor in inducing cerebral changes than impoverishment.

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77 M.R. Rosenzweig, E.L. Bennett and M.C. Diamond, "Transitory Components of Cerebral Changes Induced by Experience", *Proceedings, 75 th. Annual Convention, A.P.A.*, Vol. 2, 1967, p. 105-106.

78 Denenberg, *Op. Cit.*, p. 338.

79 E.L. Bennett, M.C. Diamond, D. Krech and M.R. Rosenzweig, "Chemical and Anatomical Plasticity of Brain", *Science*, Vol. 146, 1964, p. 610-619.

One major source of criticisms of the California experiments came form pharmacologists. Weiss and Heller[80] pointed out that there has been oversimplistic speculations on the behavioral role of the cholinergic system, which arises from "the tendency to select a deceptively simple aspect of behavior as an assay, and then postulate biochemical mechanisms ..." [81] Karczmar[82] criticized the investigations of the California group from both the behavioral and biochemical viewpoints. His major objection is that "Acetylcholine level cannot be measured so precisely that 3% differences are statistically significant";[83] he therefore questioned the accuracy and significance of the small differences in acetylcholine-esterase activity obtained by the California group.

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80 B. Weiss and A. Heller, "Methodological Problems in Evaluating the Role of Cholinergic Mechanisms in Behavior", Federation Proceedings, Vol. 28, No. 1, 1969, p. 135-146.

81 Weiss and Heller, Op. Cit., p. 143.

82 A.G. Karczmar, "Is the Central Cholinergic Nervous System overexploited ?", Federation Proceedings, Vol. 28, No. 1, 1969, p. 147-157.

83 Idem, ibid., p. 155.

Bennett and Rosenzweig[84] replied to Karczmar's objections by stating that, although acetylcholinesterase activity is difficult to measure accurately to within 3%, small differences induced in the brain by differential environment are found to be highly consistent and reproducible. Furthermore, such differences tend to be in the same direction and of the same order of magnitude. The authors pointed out that "Small differences in enzymatic activities may be important ... small decreases in AChE activity, do in some cases, affect behaviour significantly"[85]

The writer wishes, in evaluating these criticisms, to point out that the California studies have been replicated many times with consistent results, and to add that consistent findings have also been obtained from more reliable measures than the AChE estimate, such as dry brain weight and glial count, which have not been mentioned by the two California critics cited above.

b. Impoverishment Studies.

Having reviewed the literature on the effects of enrichment on brain weight and chemistry, studies on impoverishment and the possible relationships between

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84 E.L. Bennett and M.R. Rosenzweig, "Comments and General Discussion", Federation Proceedings, Vol. 28, No. 1, 1969, p. 158-159.

85 Idem, Ibid., p. 158.

behavioral abnormalities and neurophysiological mechanisms are now discussed.

Two related studies by Melzack and Burns[86] and by Melzack[87] have shown that Scottish terriers and pure-bred beagles reared in isolation shared similar behavioral characteristics : high level of excitement, failure to attend selectively to environmental stimuli, abnormal response to noxious stimulation, difficulty in performing cognitive tests, social submissiveness, and extreme licking behaviour. The restricted animals also showed the following physiological characteristics : EEG showed a disproportionately large amount of high frequency components in novel situations, and the evoked responses by light flashes or clicks in the reticular formation showed fluctuating amplitudes resulting in averaged amplitude reduction, and changes in the wave form. The later components of the evoked responses were found to be more easily affected than earlier ones. Habituation rate to a novel situation was also found to be slower in the restricted dog than its littermate reared as control.

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

87 R. Melzack, "Effects of Early Experience on Behaviour : Experimental and Conceptual Considerations", in Disorders of Perception, P.H. Hoch and J. Zubin, Ed., New York, Grune and Stratton, 1965, p. 271-299.

The authors presented a conceptual model that might explain the abnormal behavior of restricted animals. They regarded the possibility of degeneration of peripheral fibres or central afferent neurons as highly unlikely. Instead, they hypothesized a process in which, as a result of severe restriction of early sensory experience, stimuli in a novel situation have no prior associations or meaning to provide for adequate selective filtering of the sensory input, consequently the total input would bombard the central nervous system mechanisms ~~that~~ thereby producing excessive sensory and affective arousal, which, in turn, would disrupt central nervous system mechanisms that underlie perceptual discrimination and adaptive response. The authors propose, in the enriched animal, that fast conducting afferents activate old memory traces in the cortex which in turn control slower afferent impulses, so that irrelevant information are filtered out and selective attention made possible. This view is in agreement with the neuronal model of Sokolov[88] and the attention model of Hernandez-Peon;[89] but

88 E.N. Sokolov, "Neuronal Models and the Orienting Reflex", in M.A. Brazier, Ed., The Central Nervous System and Behaviour, New York, J. Moon, 1960, p. 216.

89 R. Hernandez-Peon and M.B. Sterman, "Brain Functions", Annual Review of Psychology, Vol. 17, 1966, p. 363-394.

appears to oppose the hypothesis presented by the California group of investigators who favor biochemical structural changes induced by complex enriched environments. Specifically, it is not possible to predict, based on Melzack's conceptual model the generalized differences found by the California group in terms of such measures as brain size, brain weight, glial density, and cortical/subcortical cholinesterase ratios. These wide spread differences in the brains of enriched as compared with impoverished animals suggest that enrichment affects the development of the brain as a whole, and not simply a specific system such as the activating or the arousal system. The findings of the California group are more compatible with the hypothesis of neural efficiency as a result of enrichment as suggested by Edwards[90] than the findings of Melzack and coworkers.

c. Studies Contrasting the Effects of Enrichment and Impoverishment

A series of studies on the effect of differential environments on PEP latencies were conducted by Edwards[91,92,93]

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90 Edwards, Op. Cit., p. 54.

91 Idem, Ibid., 73 p.

92 H.P. Edwards, W.F. Barry and J.O. Wyspianski, Op. Cit., P. 133-138.

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

and associates. The results indicated that when rats were raised in differential environments for the first three months of life, significant differences were found between the enriched and impoverished subjects in PEP latencies, with the latencies of the enriched group being shorter, as expected, from the onset of the photic stimulus. Owing to the replication of the same findings three times at the University of Ottawa laboratory, the above evaluative summary statement appears to be justifiable. The results were not explained by any specific neuronal model, but were discussed as compatible with Ertl's findings with humans and with his neural efficiency hypothesis.

6. Summary and Hypotheses

This chapter has reviewed relevant studies designed to investigate the concept of critical periods, the relationships between evoked cortical potentials and behavior, ontogenesis of the PEP, the effects of differential environments on behavioral variables, and the effects of differential environments on neurophysiological measures.

The possible existence of critical developmental periods is worthy of investigation because it has seldom been studied with neurophysiological instruments such as the PEP for the assessment of animal behavior, and findings using behavioral variables have not been conclusive.

In the second section, studies on the relationships between PEP components and behavioral variables have been reviewed. The evidence of a possible relationship between the two has led the writer to employ PEP as a tool in this study.

The literature reviewed under the heading of PEP and age is relevant because age is being used as an independent variable. It will be used later on when longitudinal variations of PEP components are discussed.

The studies dealing with the effects of early differential environment on behavioral variables have been thoroughly reviewed. Although there is general agreement in findings that enriched animals are superior problem-solvers, perform better in learning tasks, less physically active, and less emotional, investigators have differed in emphasis on individual behavioral variables as being more relevant. Owing to this controversy, several behavioral measurements are included in the present design of the exp eriment.

The last section reviews studies that link differential environments to brain chemistry and anatomy, and electrical activities in the brain.

On the basis of the findings three hypotheses are formulated below :-

1. When albino rats reared in an enriched environment beginning at four weeks, eight weeks and twelve weeks of life and for periods of twelve weeks, eight weeks and four weeks respectively, and rats reared in an impoverished environment throughout the experimental period of twelve weeks are compared, the four groups should show measurable differences in PEP components recorded at four week intervals.

In its null form, this hypothesis states that :

> When albino rats reared in an enriched environment beginning at 4,8, and 12 weeks of life and for periods of 12,8, and 4 weeks respectively, and rats reared in an impoverished environment throughout the experimental period of 12 weeks are compared, the four groups show no significant differences in latencies and amplitudes of four PEP events and in the wave form variability at 8, 12 and 16 weeks of life.

2. When albino rats reared in an enriched condition beginning at four, eight, and twelve weeks of age and rats brought up in the impoverished condition throughout the experimental period of twelve weeks are compared at four week intervals, the four groups should show measurable differences in their performance on a brightness discrimination task, a Shuttle Box avoidance learning experiment, a Skinner operant task, an activity measure, and an emotionality evaluation.

In its null form, this hypothesis states that :

> When albino rats reared in an enriched condition beginning at 4, 8, and 12 weeks of age and rats brought up in an impoverished condition throughout the experimental period of 12 weeks are compared at four week intervals, there are no significant differences among the four groups in Brightness Discrimination scores, avoidance learning scores, operant behavior, activity score, and emotionality ratings.

3. When four groups of albino rats defined respectively as : enriched from weaning to the age of sixteen weeks; impoverished from weaning to the age of eight weeks and subsequently enriched to the age of sixteen weeks; impoverished from weaning to the age of twelve weeks and then enriched to the age of sixteen weeks; and impoverished throughout the experimental period of ~~sixteen~~ twelve weeks; are compared, there should be significant differences among the four groups in their PEP development.

The null form reads :

> When the longitudinal changes in the latencies and amplitudes of four PEP events and in the wave form variability, as well as the direction of these changes are compared among four groups of albino rats, defined respectively as : enriched from weaning to the age of sixteen weeks; impoverished from weaning to the age of eight weeks and then enriched to the age of sixteen weeks; impoverished from weaning to the age of twelve weeks and then enriched to the age of sixteen weeks; and impoverished throughout the experimental period of twelve weeks, there ~~sh~~ are no significant differences among the four groups in their PEP development.

CHAPTER II

EXPERIMENTAL DESIGN

This chapter gives a detailed description of the experimental design by means of which the hypotheses stated in the first chapter are tested. It describes the sample, the tools used, the experimental procedure, and the statistics employed in the analysis of the data.

1. The Sample.

The sample consisted of sixteen male albino rats of the Sprague-Dawley strain in litters of four. They were obtained immediately after weaning, at approximately twenty-one days old. This strain was chosen because it has been used in previous studies in the University of Ottawa laboratory and is less emotional than other varieties.

2. The Tools.

This section describes the tools used in this experiment. The electronic apparatus for the recording of *PEP* is described first, followed by a description of behavioral tests.

The procedures for recording *PEP* were essentially as described in a previous study by Edwards et al.[1] The same procedure was applied to all subjects.

The subject was restrained in an E & M[2] plastic holder. Three Grass needle electrodes were then placed in the scalp, as shown in Fig. 1, 2 mm. apart and directly above the right parietal-occipital portion of the skull. The points of the needles were 3 mm. to the right of the midline and 2-4 mm. anterior to the inion depending on the size of the animal's skull. Two reference Grass needle electrodes were attached to the tail subcutaneously. The electrodes were connected to two Mousseau Differential amplifiers Model SA-3 matched for gain at 60 K and set to filter at 1-60 cps with an attenuation slope of 6 db per octave roll off. The amplifiers were in turn connected to two input channels of a four channel FM tape recorder Model T 3000, the outputs of which passed through a Kronhite band-pass filter set at 3-50 cps at 0 db down with an attenuation of 18 db per octave roll off, and fed into a monitoring oscilloscope and a Nuclear Data 1024 Enhancetron averaging computer. A Tektronix Dual-Beam Oscilloscope Type RM 565 was employed to display the averaging data.

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

2 E & M denotes the manufacturer.

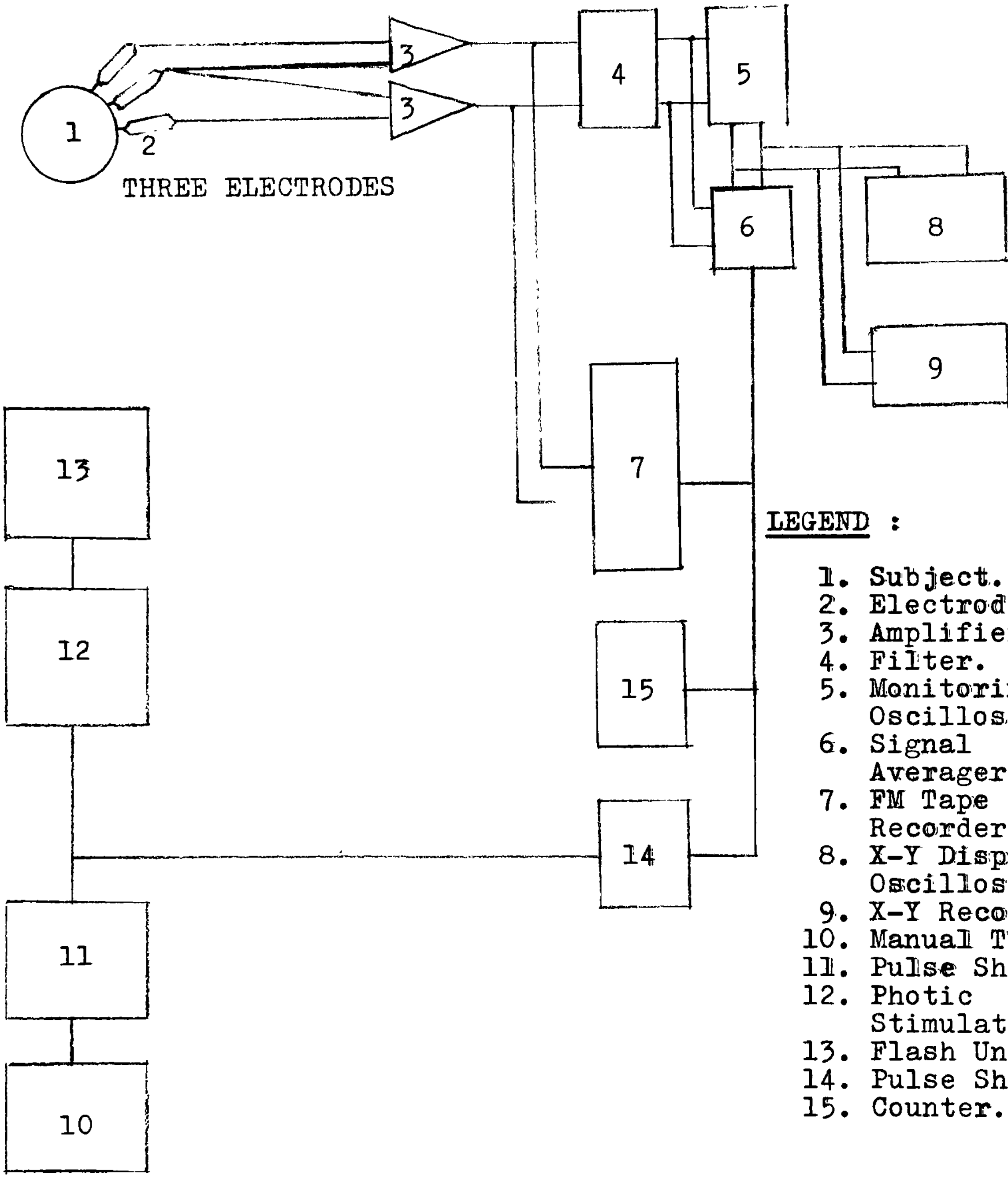
Photic stimuli were provided by means of a Nihon Kohoen photic stimulator triggered manually with a Rutherford pulse generator Model B14-R. Pulses were fed to Channel three of the FM tape recorder and to the trigger input of the Enhancetron averaging computer.

During the experiment, the computer sampled EEG records over the 500 msec. following each flash and summated these records over one hundred flashes. The averaged PEP were then plotted on Hewlett-Packard/Moseley graph paper, by means of Moseley X-Y recorder, prior to PEP components and wave form variability analysis.

A diagrammatic representation of the equipment used to obtain PEP described above is given in Fig. 1.

Ability to solve a brightness discrimination problem was tested using a two-choice apparatus patterned after Thompson and Bryant[3]. It consisted of a starting box 9 in. long, 7 in. wide and 13 in. high; a V-shaped choice chamber 28 in. long, 8 in. wide at its narrow side adjacent to the staring box, 12 in. wide at its widest towards the other end, and 13 in. high; and two identical goal boxes, 9 in. long, 7 in. wide and 13 in. high, placed

3 R. Thompson and J.H. Bryant, "Memory as Affected by Activity of the Relevant Receptor", Psychological Reports, Vol. 1, 1955, p. 393-400.



LEGEND :

1. Subject.
2. Electrodes.
3. Amplifier.
4. Filter.
5. Monitoring Oscilloscope.
6. Signal Averager.
7. FM Tape Recorder.
8. X-Y Display Oscilloscope.
9. X-Y Recorder.
10. Manual Trigger.
11. Pulse Shaper.
12. Photic Stimulator.
13. Flash Unit.
14. Pulse Shaper.
15. Counter.

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

side by side. The starting box was separated from the choice chamber by a sliding gate, and the choice chamber was separated from the goal box by a wall containing two windows 4 in. by 4 in. which may be covered with cards 3 in. by 3 in. of different brightness, locked or unlocked. A wall 6 in. long protruded into the choice chamber separating the two windows. The floor of the starting box and the choice chamber consisted of three grids made from brass rods set 1/4 in. apart. The grids could be electrified by the experimenter by means of a variac shocker adjusted to deliver shocks to the magnitude of 120 volt, 1 amp., which could be manually scrambled. The three grids were arranged as follows: one covered the floor of the starting box; another covered the floor area of the choice chamber except for the 6 in. nearest the windows, and the third covered the floor area nearest the windows. The third grid was divided into independent right and left halves. Thus these four areas could be activated independently.

Ability to learn an avoidance task was tested by means of a Shuttle Box manufactured by Lafayette Model A584. This is a commercially available automatic shuttle system consisting essentially of two chambers separated by a guillotine door. The floors of the chambers consist of grids made from brass rods set 1/4 in. apart. The apparatus is constructed of metal except for two windows from which the animals could be observed. The apparatus is designed for the presentation of classical conditioning paradigms whereby it is the subject's task to respond to a conditioned stimulus which may be either a light or a buzzer by running from one chamber to the other prior to the presentation of scrambled shock which acts as the unconditional stimulus, and which is delivered by a Variac shocker set at 120 volts, 0.5 mA with 90 % interrupter. The apparatus includes as some of its salient features automatic printing of responses, automatic event timer, and otherwise fully automatic operation.

Operant behavior consisting of a lever-pressing task for contimuous food reinforcement was tested by means of a Scientific Prototype rodent test cage. It consisted of a test cage 8 in. wide, 9 in. long, and 8 in. high, with a 'piggy-back' control unit, plastic top, and aluminium end panels. The set up included food tray, water bottle, fixed pedal lever, and food pellet dispenser. A cumulative response plotter was wired to the pedal lever. Noyes food pellets were used as positive reinforcement.

Activity level in a novel situation was measured by means of a Lafayette activity platform Model 501. The apparatus consisted of a 12 in. by 12 in. platform, an activity sensing transducer, a metal enclosure, and an amplifier. The platform was a metal grid supported on a wooden base. The transducer was a light source and a photo-electric cell which was activated by up and down movements of the metal grid made by the animal placed on the platform. A mechanical wedge adjust lever was provided to allow adjustment of the platform sensitivity for different weight animals. The amplifier had a voltage output for an oscilloscope and a switch closure output for an impulse counter.

The degree of emotionality was measured by means of a rating scale (Appendix 8) constructed specially for the purposes of this experiment. The overall emotional reactivity was determined by the overall results on seven scales : a five-point defecation scale, a four-point urination scale, a three-point squealing scale, a three point exploration scale, a three-point fearful~~l~~ness-apprehension scale, a four-point aggressiveness scale, and a four-point arousal-attention scale. All subjects were evaluated on these scales just prior to or during each <u>PEP</u> recording.

The seven scales were chosen from literature on the emotional reactivity of the rat, especially from experiments performed at Purdue University. A factorial study by Whimbey and Denenberg[4], who employed a battery of tests on emotional reactivity and factor analysed their intercorrelations, has found that one of the factors extracted (Factor 1) labelled as 'emotional reactivity' had positive loadings on such tests as 'emotional rating' which was operationally defined as a two-point scale : 1 for 'tried to escape'; 0 for 'did not try to escape when led out of the cage', and defecation in the avoidance learning unit in the open field. Factor 1 also had negative loadings from such tests as : time in the novelty box and number of crossings in the novelty box. The novelty box experiment was interpreted not simply as measuring curiosity or exploration, but as measuring fearfulness also, owing to the noise created by the equipment which caused the animals to run away or freeze. In the light of this and other studies, the seven scales mentioned above were chosen. They were found to be satisfactory in trial tests. While believed to be correlated to some degree, the scales are considered distinct enough to merit separate ratings.

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4 A.E. Whimbey and V.H. Denenberg, "Programming Life-Histories : Creating Individual Differences by the Experimental Control of Early Experiences", *Multivariate Behavioral Research*, Vol. 1, No. 3, 1966, p. 279-286.

The number of descriptive categories was determined by the ability on the part of the experimenter to discriminate animal behavior. For the sake of objectivity, and to reduce halo, ratings were performed blind and each scale was rated separately. Rating was done at various times during each *PEP* session. For example, reaction to a novel situation, the presence or absence of freezing posture and tendency to escape were observed immediately after the subjects were brought out of their cages, while defecation and urination, being quantifiable, were measured towards the end of the *PEP* session. Squealing, aggressiveness and arousal were assessed ~~wer~~ at intervals. Because of the unavailability of an absolute criterion for emotionality and because the validity of each individual scale has not been adequately established in the literature, the seven scales were assigned equal weights when the overall emotionality index was derived. Also, in the absence of criterion groups based on suitable physiological measures, multiple discriminant functions based on the present experimental groups would bias the results, and therefore were not computed.

3. The Experimental Procedure.

The first step in this experiment consisted of splitting four litters of Sprague-Dawley albino rats immediately upon arrival into four groups of four subjects each, according to the randomized split-litter technique whereby one subject from each litter was assigned randomly to each of the four experimental groups. In this way, all four groups contained one littermate from each litter, and it is assumed that the four groups were homogeneous.

The subjects were then earmarked and weighed. There were no significant differences in weight among the four groups. Prior to differential rearing, PEP was recorded for all subjects. It was found that the PEP latencies and amplitudes did not differ significantly among the four groups. This additional information agreed with the assumption that the four groups were equivalent at the start of the experiment as inherent in the randomized split-litter technique.

The PEP was obtained in a darkened and quiet room, using the equipment described in the preceding section. The subject was placed 14 in. away from the light source, awake but immobilized. The 100 light flashes were triggered manually at a random rate of not more than one every two seconds. According to Kimura[5], the best occipital PEP records were obtained when the electrodes were placed two to four mm. from the midline and five to six mm. posterior to the coronal suture. Owing to the uncertainty of actual electrode placements and to the fact that PEP have been found to alter with changes in placements, three scalp electrodes were employed, placed along a saggital plane 2 mm. apart, the anterior two corresponding to the locations of Kimura[6] and Edwards[7]. The middle electrode was connected to both amplifiers. The two records thus obtained were then compared with regard to latencies and amplitudes of the PEP events and the variability of the wave form, and were accepted if no or little differences were found between them. Their average was then used for statistical analysis. Should they have differed, the PEP recordings were repeated. Since only those events that were time-locked to the photic stimulus were summed, myogenic contaminants and other muscle artifacts not time-locked were assumed to be averaged out.

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5 D. Kimura, "Multiple Response of the Visual Vortex of the Rat to Photic Stimulation", EEG and Clinical Neurophysiology, Vol. 14, 1962, p. 115-122.

6 *Idem*, *ibid*., p. 115-122.

7 H.P. Edwards, "Effects of Early Rearing in Differential Environments on the Rat's Photic Evoked Potentials", Unpublished Doctoral thesis presented to the Faculty of Psychology at the University of Ottawa, Ontario, 1967, p. 35.

Pupillary reflexes and autonomic arousal known to contaminate PEP were reported by Edwards[8] as insignificant because group differences were small, hence these possible contaminants were not considered to affect PEP records significantly in the present investigation.

A major exception from the procedure described in a previous study by Edwards *et al.*[9] was that the PEP measurements were not obtained from photographs of oscilloscope displays, but from X-Y plots on standardized graph papers. Each graph was dated and numbered with the animal's identification, but the environment condition of the subject was unknown. Another exception was that, instead of measuring only the vertex which is the event with the greatest amplitude and a slow afferent with a typical latency of not less than 20 msec., in the present investigation, four events were identified on the basis of a typical averaged group PEP record. This was done according to the suggestion made by Edwards *et al.*[10] in a later publication. Although Szerb[11] concludes that amplitudes

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8 Edwards, *Op. Cit.*, p. 6-11.

9 Edwards, Barry and Wyspianski, *Op. Cit.*, p. 85-92.

10 H.P. Edwards, W.F. Barry, 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. 137.

11 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.

of later components of evoked potentials is related to the functioning of the cholinergic synapses, it was the writer's opinion that in the absence of an objective criterion for the determination of the most relevant event, events found to reproduce reliably and between latencies of 40 to 300 msec. should be measured and used in the analysis. Four events, two positive and two negative, were identified in this way.

The same procedure was repeated for all subsequent PEP recordings.

Group one subjects were immediately introduced to the enriched condition, which is defined as two identical wire mesh cages, 48 in. long, 30 in wide and 18 in. high, containing a variety of toys such as plastic balls, plastic toys, an activity wheel, tunnels, ladders, and paper designs painted black and white. All four subjects inhabited one cage at a time, being changed from one cage to the other at weekly intervals for cage cleaning purposes. The toys were replaced rather frequently, especially the paper designs, owing to the destructive nature of the rodents. Both cages were provided with two swinging doors, allowing the experimenter to handle and play with the rats for 15 min. every evening, since handling has been found[12] to affect later

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12 V.H. Denenberg, "Critical Periods, Stimulus Input, and Emotional Reactivity : A Theory of Infantile Stimulation", Psychological Review, Vol. 71, 1964, p. 335-351.

emotional reactivity. In its essentials, the enriched environment was similar to that described by Hymovitch[13] and by Edwards[14].

The other three groups were retained in the impoverished condition, which is defined as small wire-mesh cages 10 in. long, 8 in. wide, and 6½ in. high, the front of which was made of 1/4 in. wire-mesh and faced a blank wall, while all the other sides were made of aluminium sheets, so that perceptual patterning was restricted. Each cage was inhabited by a single animal. In its essentials, the impoverished environment used in this study was similar to those described in the literature.

Relevant physical conditions such as light, air, noise, smell, water and food supply, and temperature were maintained constant for all subjects throughout the experiment.

As a second step in this experiment, after maintaining the subjects in the differential environments described above for four weeks, a second PEP was recorded, and the animals were tested on the Brightness Discrimination task and the emotionality rating scale.

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13 B. Hymovitch, "The Effects of Experimental Variations on Problem-Solving in the Rat", Journal of Comparative and Physiological Psychology, Vol. 45, 1952, p. 134.

14 Edwards, Op. Cit., p. 32.

The Brightness Discrimination task was divided into three stages. The first stage was to pretrain the animals to go from the starting box to the goal box through open windows. If the subject, when placed in the starting box and facing the sliding door which was subsequently opened, failed to leave the starting box within five seconds it was given a brief shock. After twenty sec. in the choice chamber, if the subject failed to run through the open windows, it was given another brief shock. Brief shocks were given until the subject had reached the goal box. The subject was given a forty-five sec. rest, as the inter-trial period, while awaiting the next trial. One trial was defined as a complete run from the starting box to the goal box. A correct trial was defined as one with no shock applied either in the starting box or in the choice chamber. This first stage was ended when the subject succeeded in three consecutive trials. The second stage was similar to the first except that now the windows leading to the goal box were covered with two identical black and white striped cards. In addition, the windows were now almost closed but unlocked, so that a light push was required from the subject in order to reach the goal box. As before, the second stage was completed when the subject made three correct consecutive trials. The third and final stage was the actual test for problem-solving. As before, shock delays were five sec. for the starting box and twenty sec. for the choice chamber, with a forty-five sec. intertial period. However, the windows were now covered with solid white and black cards, the former being the positive stimulus and always unlocked, the latter the negative stimulus and always locked. The cards were alternated according to a pre-arranged random sequence. While in the choice chamber, if the animal came within six in. of the black window, it was shocked briefly. This was defined as an incorrect trial, which ended whenever the subject finally reached the goal box through the white window. A correct trial was defined as one in which the animal reached the goal box through the white window without the application of shock. Each subject was tested to the criterion performance of eight correct consecutive trials out of ten trials. The score was the total number of trials needed to attain criterion performance. Testing was discontinued after fifty trials if criterion performance had not been reached, hence the maximum possible score was fifty. Enriched and impoverished animals were tested in a random seq uence.

At this point (Age 8 weeks), the Group 2 subjects were transferred to the enriched environment. Four weeks later, at the age of twelve weeks, a third series of tests was carried out, including once more <u>PEP</u> records and emotionality measures, and this time including as behavioral test the Shuttle Box avoidance learning experiment.

As described in the previous section, the shuttle box employed was an automatic shock avoidance apparatus which used a buzzer as the conditioned stimulus and shock as the unconditioned stimulus, and running from one chamber to the other as the response. The subject was placed in the right chamber facing the guillotine door, and was left there foe five min. for it to become adjusted to the novel surroundings. At the end of this period,the control unit was switched on. The timing device was previously adjusted to present the following sequence : door opening, stimulus buzzer for 10 sec., shock delay for 7 sec., shock for 3 sec., and intertrial intervals of 18, 20, 22 sec. set for automatic random selection. The door opened at the start of each trial, the animal responded by crossing the door to the opposite chamber, following a door delay of 0.8 sec. The maximum trial length for this paradigm was 10.8 sec. Failure of the animal to cross from one chamber to the other prior to the start of shock was defined as an incorrect trial. If the subject succeeded in crossing before the shock was applied, that is, less than 7 sec. after the start of the trial is defined as a correct trial or an avoidance response. Prior to the actual testing, all subjects were pretrained to run from one chamber to the other with the door open whenever shocked. In the actual testing, each subject was tested to the criterion performance of nine consecutive correct avoidance responses out of ten trials. A maximum limit of 150 trials was set in order not to shock the animals excessively. The score was the total number of trials to attain the criterion performance. The enriched and impoverished animals were tested in random sequence, as in all other measurements.

At this point (age ; 12 weeks), the subjects of group three were transferred to the enriched environment to join groups one and two. Four weeks later, at the age of 16 weeks, the fourth step of the experiment or final testing session was carried out. The step consisted of PEP recording, emotionality measure, Skinner operant behavior testing, and activity measure.

Operant behavior was measured using the Skinner box described previously. The animal was placed in the box facing the lever. Previous to the testing session, the subjects were kept without food for about 24 hours. Since shock was previously applied in two experimental testings, the reinforcement used here was positive, and consisted of food pellets dropped down from a dispenser set to be activated by each lever pressing according to the fully reinforced schedule. Responses were recorded on cumulative graphs for later analysis. The duration of the experiment was one hour.

Activity was measured by means of the activity platform described earlier. Since the voltage range of the amplifier was from 10 millivolts to 10 volts, and the response range was from 1 to 10 cps., the platform could detect all ordinary muscle or body movements, but not slight shiverings. For example, in walking movements, the voltage range was between 0.1 to 5 volts, and the typical response range was within the specified frequencies. The responses were identified and recorded by a cumulative counter. The duration of the experiment for each subject was one hour.

In summarizing, the procedure of this investigation consisted of randomly assigning the subjects into four groups using the split-litter technique. Prior to differential rearing subjects were pretested on the PEP and weights to determine the equivalence of groups. Group one subjects were reared in the enriched environment throughout the experiment. Group two subjects were reared in the impoverished environment for four weeks, then were transferred to the enriched condition for the remainder of the experiment. Group three subjects were similarly reared in the impoverished environment at first, for eight weeks, then were transferred to the enriched condition for the rest of the experiment. Group four subjects were reared in the impoverished environment throughout the experiment. At eight, twelve, and sixteen weeks of age, all subjects were measured on the PEP and on specific behavioral tests.

The independent variables were : the duration of enrichment and the age of the subjects when the enriched condition was introduced.

The dependent variables studied were : PEP latencies and amplitudes of four events, variability of PEP wave form, brightness discrimination score, avoidance conditioning score, Skinner's operant behavior, activity score, and emotionality rating. It is reasoned that the use of a number of relatively independent measures as dependent variables will serve as partial answer to the type of criticism that Weiss and Heller[15] make of the California studies, as mentioned in the previous chapter, when they state that the measures used in these studies were too simplistic.

4. Statistical Analysis.

In order to test the hypotheses stated at the end of the first chapter, several statistical techniques were used, the purposes of which were to establish the significance of the differences among the four groups of rats on all the dependent variables studied.

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15 B. Weiss and A. Heller, "Methodological Problems in Evaluating the Role of Cholinergic Mechnisms in Behavior", Federation Proceedings, Vol. 28, No. 1, 1969, p. 135-146.

A two way analysis of variance with repeated measures on one factor design, as described by Winer[16], was used to test the significance of the main effects of enrichment and age, henceforth denoted as factor A and factor B respectively. The effects of A and of the interaction AB were the main concern of this study. In keeping with the prerequisites of this design, the subjects were randomly selected into the experimental groups on factor A, and the order of test administration at each age level was randomized in that enriched and impoverished animals were tested in random sequence. It was assumed that carry-over effects were negligible. If such effects exist, randomizing or counter-balancing does not remove them, however, there is some chance that such effects were balanced out among the four experimental groups.

The details for the computation of F ratios will not be discussed here. However, it must be pointed out that the appropriate error term for factor A is MS error (between) otherwise known as MS subj. W. groups; and the appropriate error term for factor B and the interaction of AB is MS error (within) otherwise known as MS B× subj. W. groups. These two error terms represent a pooling of

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16 B. Winer, "Multifactor Experiments Having Repeated Measures on the Same Elements", in Statistical Principles in Experimental Design, New York, McGraw-Hill, 1962, p. 298-312.

different sources of variation which are assumed to be homogeneous.

One of the assumptions required for an F distribution is homogeneity of variance. To check this, F max test was performed on the two error terms described above. In this experiment, the critical values for these statistics having p = .05, which is the assigned significance level, are :- For SS error (between), F max .95 (4,3) = 39.2;

For SS error (within), F max .95 (4,9) = 6.31.

These critical vaues are provided by Winer[17]. However, even when the data did not satisfy the assumption of homogeneity of variance, in the absence of major violations of the assumption, the F tests given in the testing of main effects due to A and B and their interaction AB were still considered to be robust.[18]

The Scheffe's Test for multiple comparisons, as described by Edwards[19], was used for the testing of the significance of selected comparisons. This test was chosen

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17 B. Winer, Statistical Principle in Experimental Design, New York, McGraw-Hill, 1962, p. 653. Appendix Table B.7 Distribution of F max Statistic.

18 Winer, Op. Cit. p. 305.

19 A.L. Edwards, "Scheffe's Test for Multiple Comparisons", in Experimental Design in Psychological Research, New York, Holt, Rinehart and Winston, 1968, p. 150-153.

first because it is designed for the testing of complex contrasts as well as ~~p~~ individual contrasts of pairs of means, and secondly, it is not based on the homogeneity of variance assumption. Its limitation is that it has less power than other posthoc techniques for planned orthogonal comparisons, so that larger differences are required for significance. As suggested by Scheffe, the alpha error was set at 0.10 for the present study, rather than the usual .05 level. The Sheffe's test was performed on the enrichment groups (Factor A) only, with the age factor controlled. The actual computation deserves a brief description :-
The following formula is used :-

$$MS_{Di} = \frac{Di^2}{n \sum a_{.i}^2}$$

where Di represents any given comparison of the treatment sums obtained by multiplying each of the treatment sums by the corresonding orthogonal coefficients, $a_{,i}$.
Then as a test of significance,

$$F = \frac{MS_{Di}}{S^2}$$

where S^2 is the error mean square of the analysis of variance. Since Scheffe's tests are performed only on Factor A, S^2 is MS error (between).
The obtained F value is compared with F', where F' is ~~(k/6/~~ (k - 1) times the table value of F for k-1 and k(n-1) d.f. In this case, since k=4 means, and the table value of F for

3 and 12 d.f., the computed F' values are : with alpha error set at 0.10, F' = 7.83; and with alpha error set at 0.05, F' = 10.47.

The following diagrammatic scheme is used to indicate the characteristics of the selected comparisons, with the age factor controlled, when Scheffe's test was applied :

Enrichment (Factor A)	Age (Factor B) 4	8	12	16 (weeks)	Σ
Group 1	A	B	C	D	T1
Group 2	E	F	G	H	T2
Group 3	I	J	K	L	T3
Group 4	M	N	O	P	T4

Comparison	Enrichment (Factor A)
A vs E	no vs no
A vs I	no vs no
A vs M	no vs no
E vs I	no vs no
E vs M	no vs no
I vs M	no vs no
B vs F + J + N	4 wks after 4 wks of age vs no
C vs G	8 wks after 4 wks of age vs 4 wks after 8 wks of age
C vs K+O	8 wks after 4 wks of age vs no
G vs K+O	4 wks after 8 wks of age vs no
D vs H	12 wks after 4 wks of age vs 8 wks after 8 wks of age
D vs L	12 wks after 4 wks of age vs 4 wks after 12 wks of age
D vs P	12 wks after 4 wks of age vs no
H vs L	8 wks after 8 wks of age vs 4 wks after 12 wks of age
H vs P	8 wks after 8 wks of age vs no
L vs P	4 wks after 12 wks of age vs no

Group totals across the four age levels were also compared :

Comparison	Enrichment (Factor A)
T1 vs T2	12 wks after 4 wks of age vs 8 wks after 8 wks of age
T1 vs T3	12 wks after 4 wks of age vs 4 wks after 12wks of age
T1 vs T4	12 wks after 4 wks of age vs no
T2 vs T3	8 wks after 8 wks of age vs 4 wks after 12wks of age
T2 vs T4	8 wks after 8 wks of age vs no
T3 vs T4	4 wks after 12 wks of age vs no

The Scheffe's test was primarily used to test Hypothesis 1. It was also applied to emotionality data since emotionality was evaluated at all four age levels. To compliment Scheffe's test, a simple one way analysis of variance was used to test the significance of difference among the four groups on Factor A at each age level. This one way analysis of variance, however, was chiefly used to test Hypothesis 2, where a different behavioral task was given at each age level except the first level at four weeks of age.

When the overall difference, according to F test applied in this one way analysis of variance, was significant, Duncan's multiple range test was performed for individual comparisons of the means of any two groups. This test is a more stringent test procedure than student t test, and discussed by Winer[20].

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20 Winer. Op. Cit. p. 77-104.

The one way analysis of variance of randomized design, however, requires the assumption of independence of grou ps. Since the groups were formed at the start of the experiment by the split-litter technique and were not actually independent, and, in addition, the sample tested was small, Friedman's test for matched groups by ranks was computed to compliment the analysis of variance results. The test is nonparametric and avoids the assumption of normality implicit in the analysis of variance by the use of ranks. This test is well described by Siegel[21] and Hays[22].

In the testing of Hypothesis 3, trend analysis was performed in this study, whose interest is centered in the longitudinal changes in PEP measures as a result of rearing under different environmental conditions at various ages. Its objective was to determine whether there are significant differences between the trends of the four treatment groups. It is assumed that any differences found among the trends are the results of different duration and timing of enrichment. A test of significance provides a basis for determining whether the difference in the trends for the four

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21 S. Siegel, Nonparametric Statistics for the Behavioral Sciences, New York, McGraw-Hill, 1956, p. 166-173, and Table N for critical values of Friedman Statistics, p.281.

22 W. Hays, Statistics for Psychologists, New York, Holt, Rinehart and Winston, 1963, p. 640-641.

groups is significant. Profiles of group means for successive observations after each experimental period of enrichment were plotted for visual examination. The detailed computational procedures will not be discussed here. The reader is referred to Edwards[23] and Winer[24] for a detailed description of trend analysis. It must be pointed out, however, that since there are four age levels, it is necessary to compute for linear, quadratic, and cubic trends, and the group differences in these trends. The error term used in determining F ratios is MS error (within).

Finally, a comment must be made on the null hypothesis decision procedure employed in the present study, in order to clarify certain issues involved in the statistical analysis. First, an overall statistical analysis was always performed to exclude chance findings. However, even if an overall test failed to reject the null hypothesis at a conventional level of significance ($p = .05$), post hoc statistical tests,such as Shheffe and trend analysis of the interaction AB, were still performed. The purpose of this was not to reject the null hypothesis, but to help suggest new hypotheses for further research, particularly since the size of the present sample was small,

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23 Edwards, Op. Cit. "Trend Analysis" p. 271-287; and Table XI, Coefficients for Obtaining linear, quadratic and cubic Components of Treatment SS, p. 435.

24 Winer, Op. Cit. "Computation of Trend Components", p. 273-278.

significant overall difference is difficult to obtain.

As pointed out by Rosenthal :-

> If an investigator finds the p associated with an overall test very high but sees a strong relationship in some subset of his data, it is not accurate to say that the subset comparison is invalid or unwarranted. 25

and,'correct inference depends not only on statistics, but also on good judgement'.[26] In the present study, the level of significance chosen in advance of any statistical procedure is $p = .05$ for the majority of tests, and $p = .10$ for the Scheffe technique, because the latter is a very conservative test. For the sake of convenience, p values less than .10 will all be reported.

5. Restatement of Specific Hypotheses.

Since in the three major hypotheses stated in Chapter 1 separate criterion variables are present, and since each variable is tested independently, specific hypotheses are stated below :-

> When four groups of albino rats defined respectively as : enriched from weaning to the age of 16 weeks; impoverished from weaning to the age of 8 weeks and subsequently enriched to the age of 16 weeks; impoverished from weaning to the age of 12 weeks and

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25 R. Rosenthal, "Experimental Expectancy and the Reassuring Nature of the Null Hypothesis Decision Procedure", _Psychological Bulletin_, _Monograph Supplement_, Vol 70, No. 6, Part 2, issue of December, 1968, p. 36-37.

26 _Idem_, _Ibid_., p. 35.

subsequently enriched to the age of 16 weeks; and impoverished throughout the experimental period of 12 weeks are compared, there are no significant differences among the groups in :-

1.1 Latencies of event 1 when these measures are taken at 4 week intervals of 4, 8, 12, and 16 weeks of life.

1.2 Latencies of event 2 when these measures are taken at 4 week intervals of 4, 8, 12, and 16 weeks of life.

1.3 Latencies of event 3 when these measures are taken at 4 week intervals of 4, 8, 12, and 16 weeks of life.

1.4 Latencies of event 4 when these measures are taken at 4 week intervals of 4, 8, 12, and 16 weeks of life.

1.5 Amplitudes of event 1 when these measures are taken at 4 week intervals of 4, 8, 12 and 16 weeks of life.

1.6 Amplitudes of event 2 when these measures are taken at 4 week intervals of 4, 8, 12 and 16 weeks of life.

1.7 Amplitudes of event 3 when these measures are taken at 4 week intervals of 4, 8, 12 and 16 weeks of life.

1.8 Amplitudes of event 4 when these measures are taken at 4 week intervals of 4, 8, 12 and 16 weeks of life.

1.9 Variability of the PEP waveforms when these measures are taken at 4 week intervals of 4, 8, 12, and 16 weeks of life.

2.1 Performances on a brightness discrimination task at 8 weeks old.

2.2 Performances on a shuttle box experiment at 12 weeks old.

2.3 Performances on an operant task at 16 weeks old.

2.4 Performance on an activity task at 16 weeks old.

2.5 Emotionality ratings when these measures are taken at 4 week intervals of 4, 8, 12, and 16 weeks of life.

3.1 Developmental profiles and thier linear, quadratic and cubic trend components of latencies of event 1.

3.2 Developmental profiles and their linear, quadratic and cubic trend components of latencies of event 2.

3.3 Developmental profiles and their linear, quadratic and cubic trend components of latencies of event 3.

3.4 Developmental profiles and their linear, quadratic and cubic trend components of latencies of event 4.

3.5 Developmental profiles and their linear, quadratic and cubic trend components of ~~latencies of~~ event 1.amplitudes.

3.6 Developmental profiles and their linear, quadratic and cubic trend components of event 2 amplitudes.

3.7 Developmental profiles and their linear, quadratic and cubic trend components of event 3 amplitudes.

3.8 Developmental profiles and their linear, quadratic and cubic trend components of event 4 amplitudes.

3.9 Developmental profiles and their linear, quadratic and cubic trend components of <u>PEP</u> wave form variability.

3.10 Developmental profiles and their linear, quadratic and cubic trend components of emotionality ratings.

CHAPTER III

PRESENTATION AND DISCUSSION OF RESULTS

In this final chapter, results will be first presented and then discussed. Implications for future research will be suggested.

1. Results of the Tests of Significance.

a. Tests for Homogeneity of Variance.

As a check for homogeneity of variance, the F max statistic was used. Table I summarizes the results of F max tests on the variances that were pooled to form the two error terms described in chapter two. The majority of F max tests did not exceed the critical values, which indicate that the hypothesis of homogeneity was not contradicted by the experimental data, hence the assumption for the F test was not seriously violated in the case of latency and amplitude of PEP events, variability of the PEP wave form, and emotionality. However, the SS error (within) for latencies of event one (F max = 11.46, $p = .05$) and of event three (F max = 7.93, $p = .05$) indicate that the subject variances of the groups were significantly different. As pointed out previously, the F test is considered robust enough not to be seriously disturbed by this violation.

Table I.-

F max Test for Homogeneity of Variance Applied to the Pooled Between and Within Error Terms of Photic Evoked Potentials and Emotionality Data.

Measure	Between Error		Within Error	
	F	P	F	P
Latency Event				
1	17.08	N.S.	11.46	.05
2	3.38	N.S.	1.95	N.S.
3	38.55	N.S.	7.93	.05
4	3.65	N.S.	2.07	N.S.
Amplitude Event				
1	11.49	N.S.	3.04	N.S.
2	3,87	N.S.	1.46	N.S.
3	1.68	N.S.	1.55	N.S.
4	1.97	N.S.	2.09	N.S.
Variability	5.03	N.S.	1.98	N.S.
Emotionality	7.33	N.S.	3.74	N.S.

b. Analysis of Variance on Enrichment and Age Factors and Their Interaction.

Tables II to XI summarizes the results of analysis of variance on PEP variables, PEP wave form variability and emotionality.

On the enrichment factor, in general, the data failed to reject the hypothesis that the variance contributed by the main effect due to enrichment is insignificant. This means that the overall results on PEP and emotionality measures for the four groups, which differed in enrichment, did not differ significantly at the .05 level.

On the age factor, in general, results were inconclusive. While the majority of F ratios did not exceed the critical values, the variances contributed by the age factor for Latency of Event One ($F = 4.54$, $p = .01$); amplitude of Event One ($F = 3.70$, $p = .05$); and amplitude of Event Four ($F = 7.83$, $p = .01$); and emotionality ($F = 2.93$, $p = .05$); were statistically significant. This indicates that, in this particular experiment, aging produced measurable effects on the variables stated above. This finding is in agreement with studies by Rose[1] who

1 G,H, Rose, "The Development of Visually Evoked Electrocortical Responses in the Rat", Developmental Psychobiology, Vol. 1, No. 1, 1968, p. 35-40.

Table II.-

Two Way Analysis of Variance of Photic Evoked[a] Potential Latencies of Event One, Using the Repeated Measures on One Factor Design.

Source	SS	df	MS	F	P
Between Subjects					
Enrichment	106.5	3	35.5	0.28	N.S.
Subjects Within Groups	1530.5	12	127.54		
Within Subjects					
Age	295.63	3	98.54	4.54	.01
Enrichment x Age	136.37	9	15.16	0.70	N.S.
Age x Subjects Within Groups	772.0	36	21.72		
Total	2841	63			

a Photic Evoked Potential Latencies are measured in Milliseconds following the onset of photic stimulation.

TABLE III.-

Two Way Analysis of Variance of Photic Evoked Potentials[a] Latencies of Event Two, Using the Repeated Measures on One Factor Design.

Source	SS	df	MS	F	P
Between Subjects :					
Enrichment	1763.82	3	587.94	1.55	N.S.
Subjects Within Groups	4551.12	12	379.26		
Within Subjects :					
Age	1013.19	3	337.73	1.36	N.S.
Enrichment X Age	3062.43	9	340.27	1.37	N.S.
Age X Subjects Within Groups	8967.88	36	249.10		
Total	19358.44	63			

a Photic Evoked Potential Latencies are measured in Milliseconds following the onset of photic stimulation.

Table IV.-

Two Way Analysis of Variance of Photic Evoked Potentials[a] Latencies of Event Three, Using the Repeated Measures on One Factor Design.

Source	SS	df	MS	F	P
Between Subjects :					
Enrichment	5575.82	3	1858.61	2.10	N.S.
Subjects Within Groups	10613.12	12	884.43		
Within Subjects :					
Age	2540.82	3	846.94	2.24	N.S.
Enrichment x Age	7304.30	9	811.59	2.15	N.S.
Age x Subjects Within Groups	13602.38	36	377.84		
Total	39636.44	63			

a Photic Evoked Potential Latencies are measured in Milliseconds following the onset of photic stimulation.

Table V.-

Two Way Analysis of Variance of Photic Evoked Potential[a] Latencies of Event Four Using the Repeated Measures on One Factor Design

Source	SS	df	MS	F	P
Between Subjects :					
Enrichment	7248.30	3	2416.10	2.48	N.S.
Subjects Within Groups	11701.56	12	975.13		
Within Subjects :					
Age	1599.17	3	533.06	0.92	N.S.
Enrichment x Age	9059.39	9	1006.60	1.73	N.S.
Age x Subjects Within Groups	20958.69	36	582.19		
Total	50567.11	63			

a Photic Evoked Potential Latencies are measured in Milliseconds following the onset of photic stimulation.

Table VI.-

Two Way Analysis of Variance of Photic Evoked Potential[a] Amplitudes of Event One, Using the Repeated Measures on One Factor Design.

Source	SS	df	MS	F	P
Between Subjects :					
Enrichment	7.93	3	2.64	0.16	N.S.
Subjects Within Groups	203.11	12	16.92		
Within Subjects :					
Age	144.12	3	48.04	3.70	.05
Enrichment x Age	184.87	9	20.54	1.58	N.S.
Age x Subjects Within Groups	467.06	36	12.97		
Total	1007.09	63			

a Photic Evoked Potential Amplitudes are measured in microvolts.

Table VII.-

Two Way Analysis of Variance of Photic Evoked Potential[a] Amplitudes of Event Two, Using the Repeated Measures on One Factor Design

Source	SS	df	MS	F	P
Between Subjects :					
Enrichment	33.54	3	11.18	0.67	NS
Subjects Within Groups	199.70	12	16.64		
Within Subjects :					
Age	117.17	3	39.06	2.08	NS
Enrichment x Age	238.48	9	26.5	1.41	NS
Age x Subjects Within Groups	675.53	36	18.76		
Total	1264.42	63			

a Photic Evoked Potential Amplitudes are measured in Microvolts.

Table VIII.-

Two Way Analysis of Variance of Photic Evoked Potential[a] Amplitudes of Event Three, Using the Repeated Measures on One Factor Design.

Source	SS	df	MS	F	P
Between Subjects :					
Enrichment	80.51	3	26.84	1.49	N.S.
Subjects Within Groups	216.21	12	18.02		
Within Subjects :					
Age	164.17	3	54.72	2.35	N.S.
Enrichment x Age	179.02	9	19.89	0.86	N.S.
Age x Subjects Within Groups	837.05	36	23.25		
Total	1476.96	63			

a Photic Evoked Potential Amplitudes are measured in Microvolts.

Table IX.-

Two Way Analysis of Variance of Photic Evoked Potential[a] Amplitudes of Event Four, Using the Repeated Measures on One Factor Design.

Source	SS	df	MS	F	P
Between Subjects :					
Enrichment	88.27	3	29.42	1.95	NS
Subjects Within Groups	181.38	12	15.12		
Within Subjects :					
Age	598.68	3	199.56	7.83	.01
Enrichment x Age	98.54	9	10.95	0.43	NS
Age x Subjects Within Groups	917.18	36	25.48		
Total	1884.05	63			

a Photic Evoked Potential Amplitudes are measured in Microvolts.

Table X.-

Two Way Analysis of Variance of Photic Evoked Potential[a] Variability , Using the Repeated Measures on One Factor Design.

Source	SS	df	MS	F	P
Between Subjects :					
Enrichment	7.3	3	2.43	1.94	NS
Subjects Within Groups	15.06	12	1.26		
Within Subjects :					
Age	31.55	3	10.52	11.43	.01
Enrichment × Age	14.51	9	1.61	1.75	NS
Age × Subjects Within Groups	33.19	36	0.92		
Total	101.61	63			

a Photic evoked potential variability scores were obtained from a rating scale shown in Appendix 10.

Table XI.-

Two Way Analysis of Variance of Emotionality Scores[a] Using the Repeated Measures on One Factor Design.

Source	SS	df	MS	F	P
Between Subject :					
Enrichment	30.42	3	10.14	0.90	NS
Subjects Within Groups	135.81	12	11.32		
Within Subjects :					
Age	7.67	3	2.56	2.93	.05
Enrichment x Age	8.64	9	0.96	1.10	NS
Age x Subjects Within Groups	31.44	36	0.88		
Total	213.98	63			

a The scores were obtained from an emotionality rating scale shown in Appendix 8.

found that PEP wave forms changed during maturation. The direction of these changes will be discussed in the next section.

The obtained F values for Enrichment X Age interaction on the PEP and emotionality measures were statistically insignificant. The failure for the AB interaction to attain a significant value indicates that the profiles showing the longitudinal development of these variables were statistically of similar forms. To examine this visually, Figures 2 to 11 represent the profiles for each group at the four age levels on the mean PEP and emotionality measures. It is interesting to note that although the profiles were not statistically different from one another, there was an apparent tendency for the profiles to have somewhat different shapes.

c. Scheffe's Test for Multiple Comparisons on Factor A

As explained in the previous chapter, even after the overall effect due to enrichment on the PEP and emotionality measures was found to be statistically insignificant, post hoc comparisons were still performed which may generate interesting hypotheses for future research.

Tables XII to XXI summarizes the results of Scheffe's test on the PEP and emotionality measures.

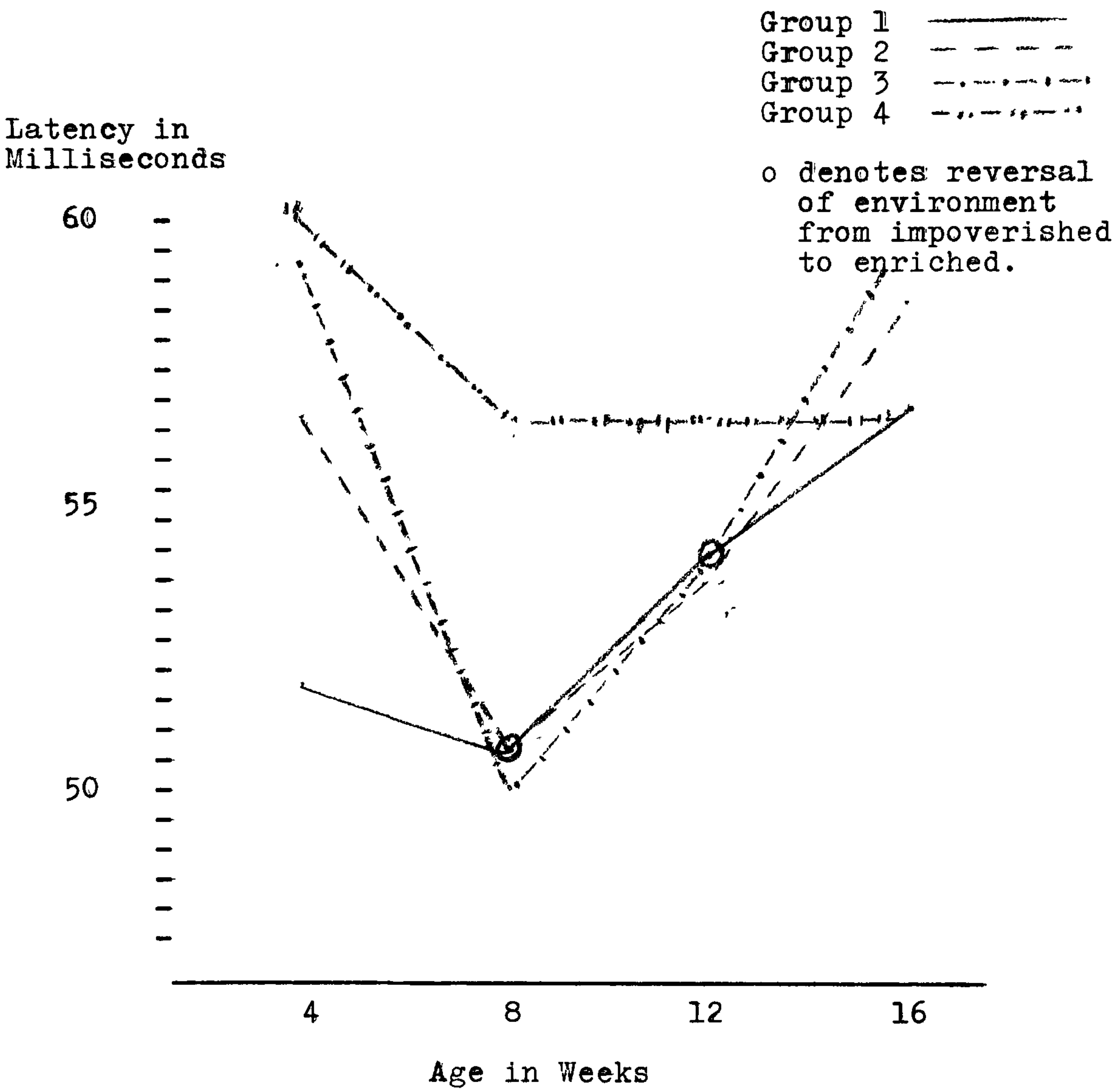

Figure 2.- Averaged Group Latencies of Photic Evoked Potentials Event One of the Four Experimental Groups at Four Age Levels.

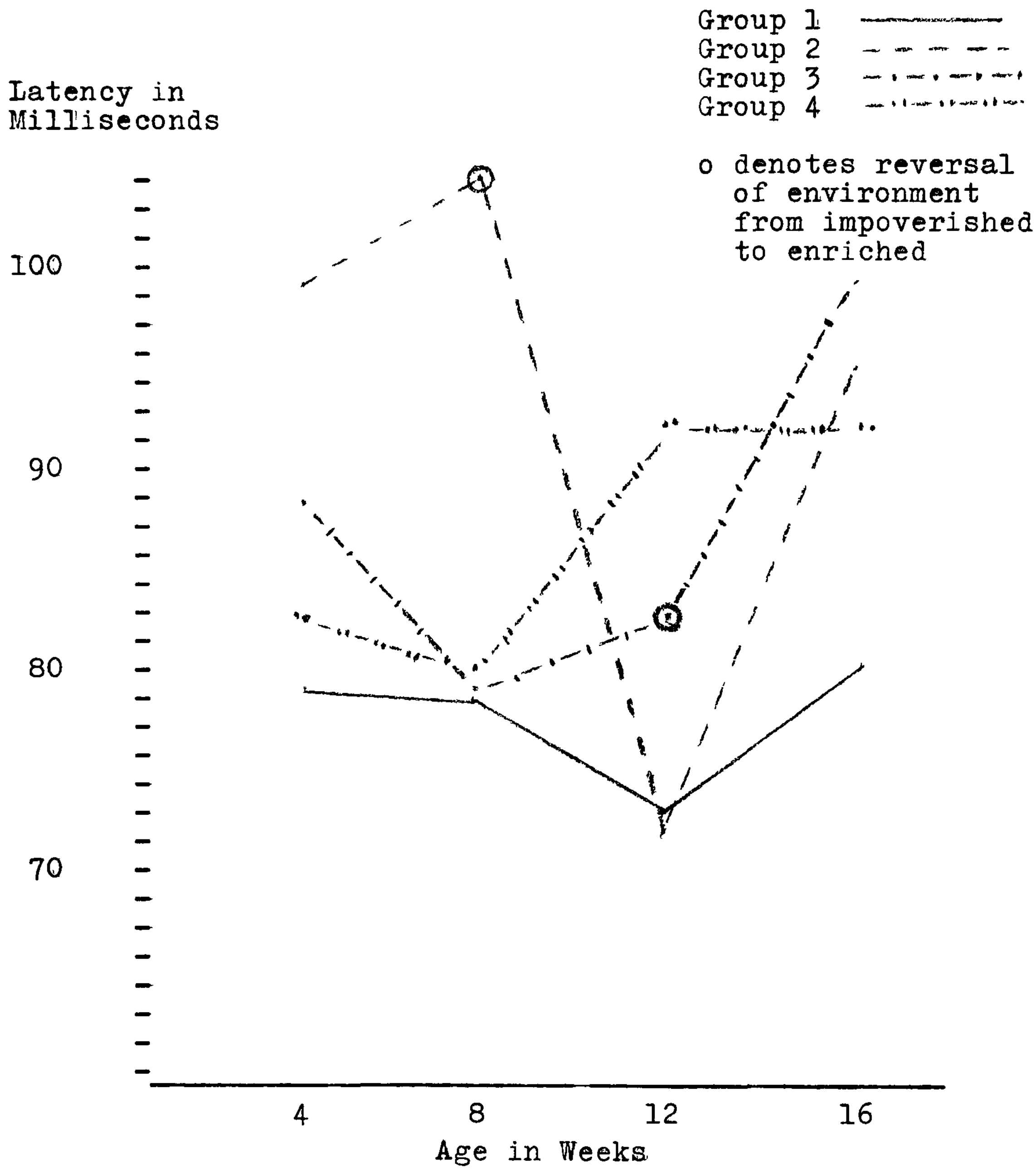

Figure 3.- Averaged Group Latencies of Photic Evoked Potentials Event Two of the Four Experimental Groups at Four Age Levels.

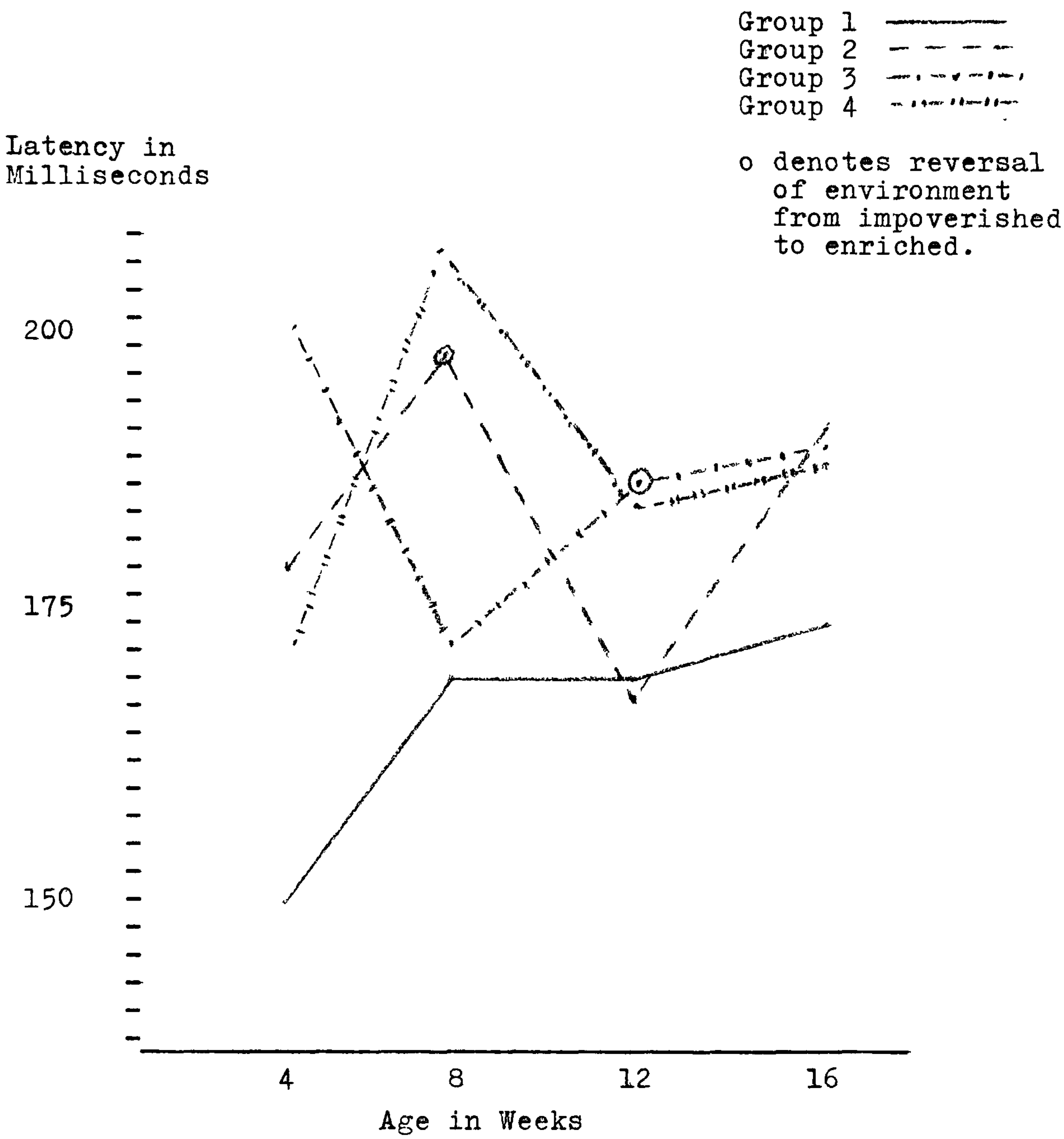

Figure 4.- Averaged Group Latencies of Photic Evoked Potentials Event Three of the Four Experimental Groups at Four Age Levels.

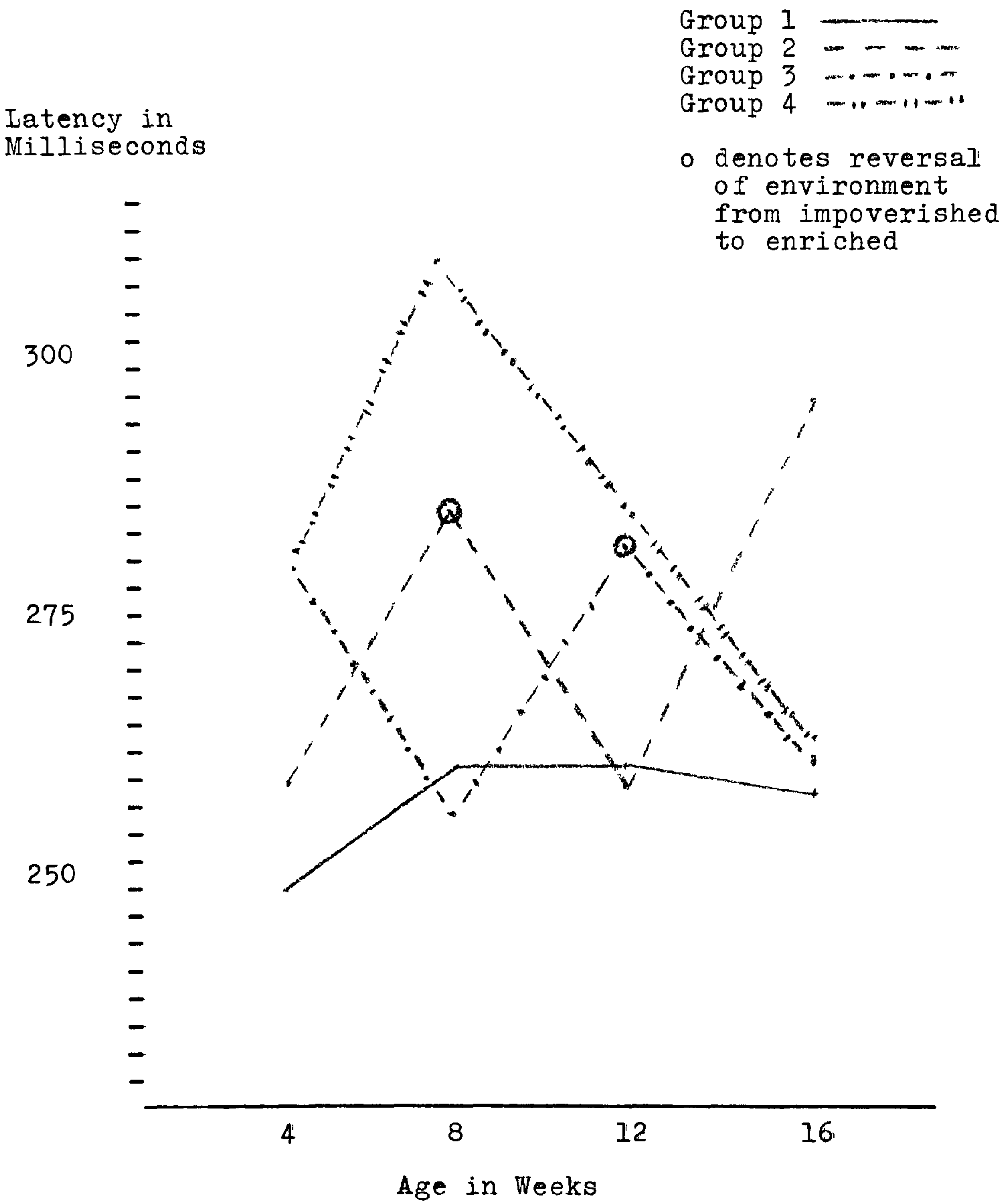

Figure 5.- Averaged Group Latencies of Photic Evoked Potentials Event Four of the Four Experimental Groups at four Age Levels.

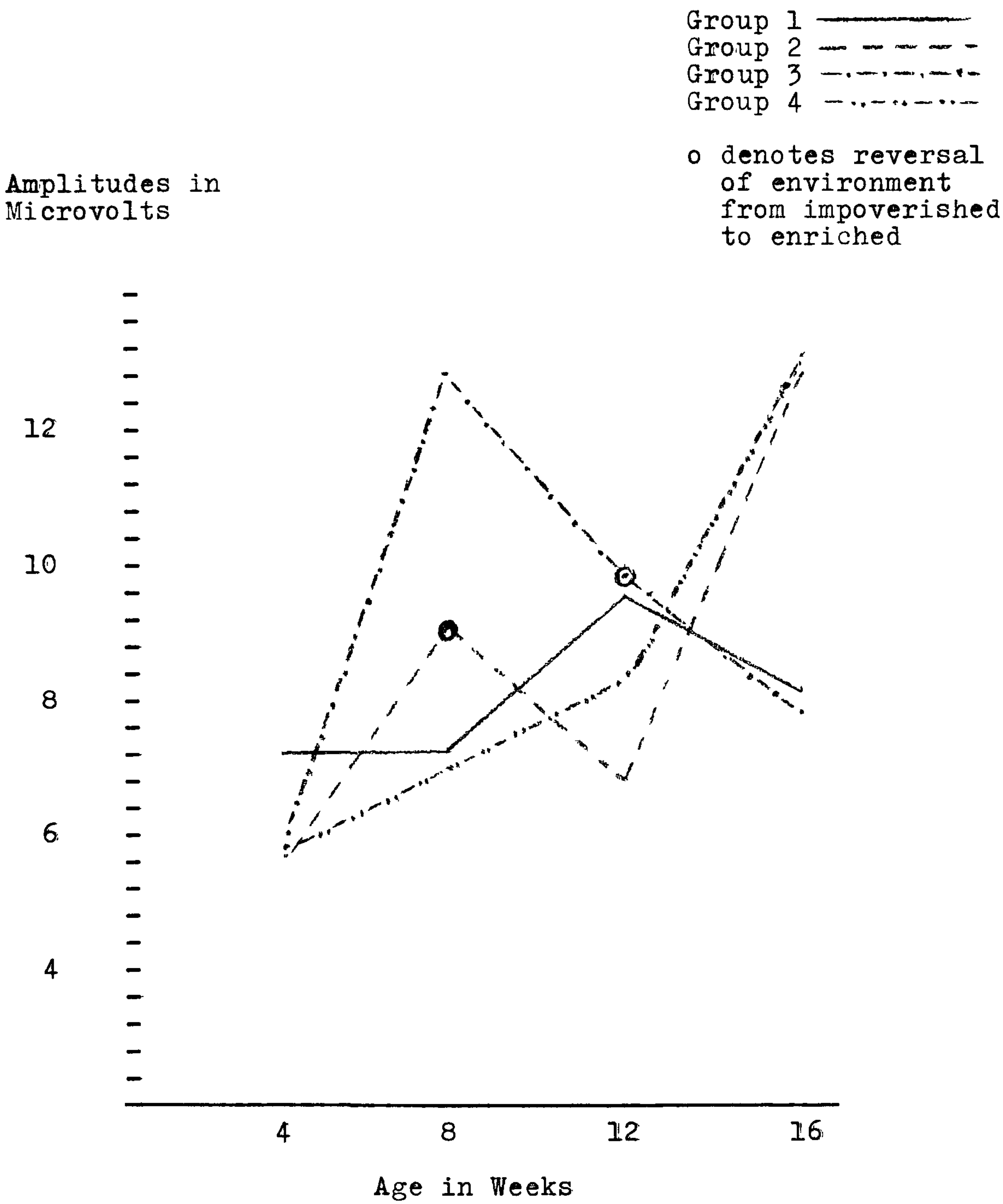

Figure 6.- Averaged Group Amplitudes of Photic Evoked Potentials Event One of the Four Experimental Groups at Four Age Levels.

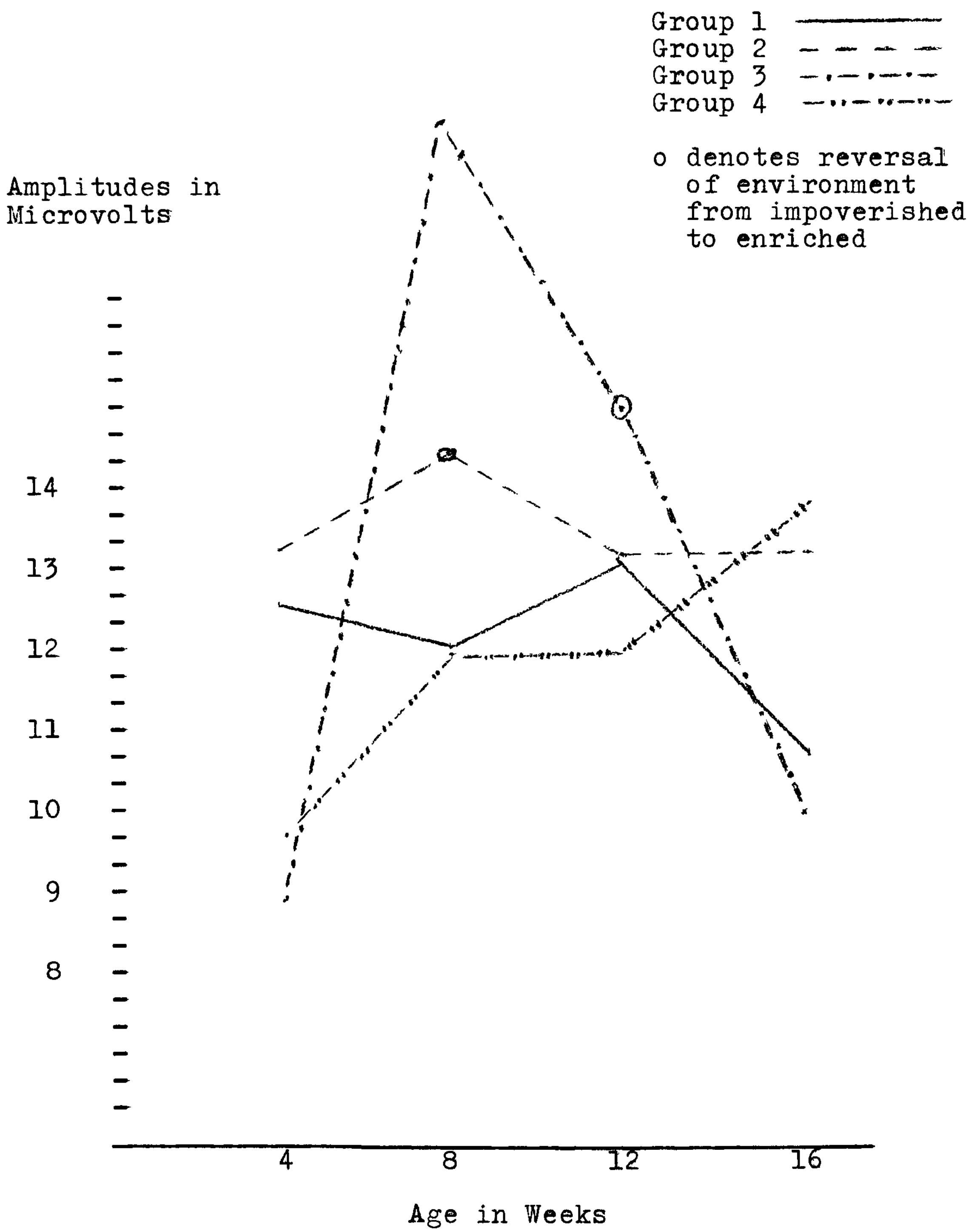

Figure 7.- Averaged Amplitudes of Photic Evoked Potentials Event Two of the Four Experimental Groups at Four Age Levels.

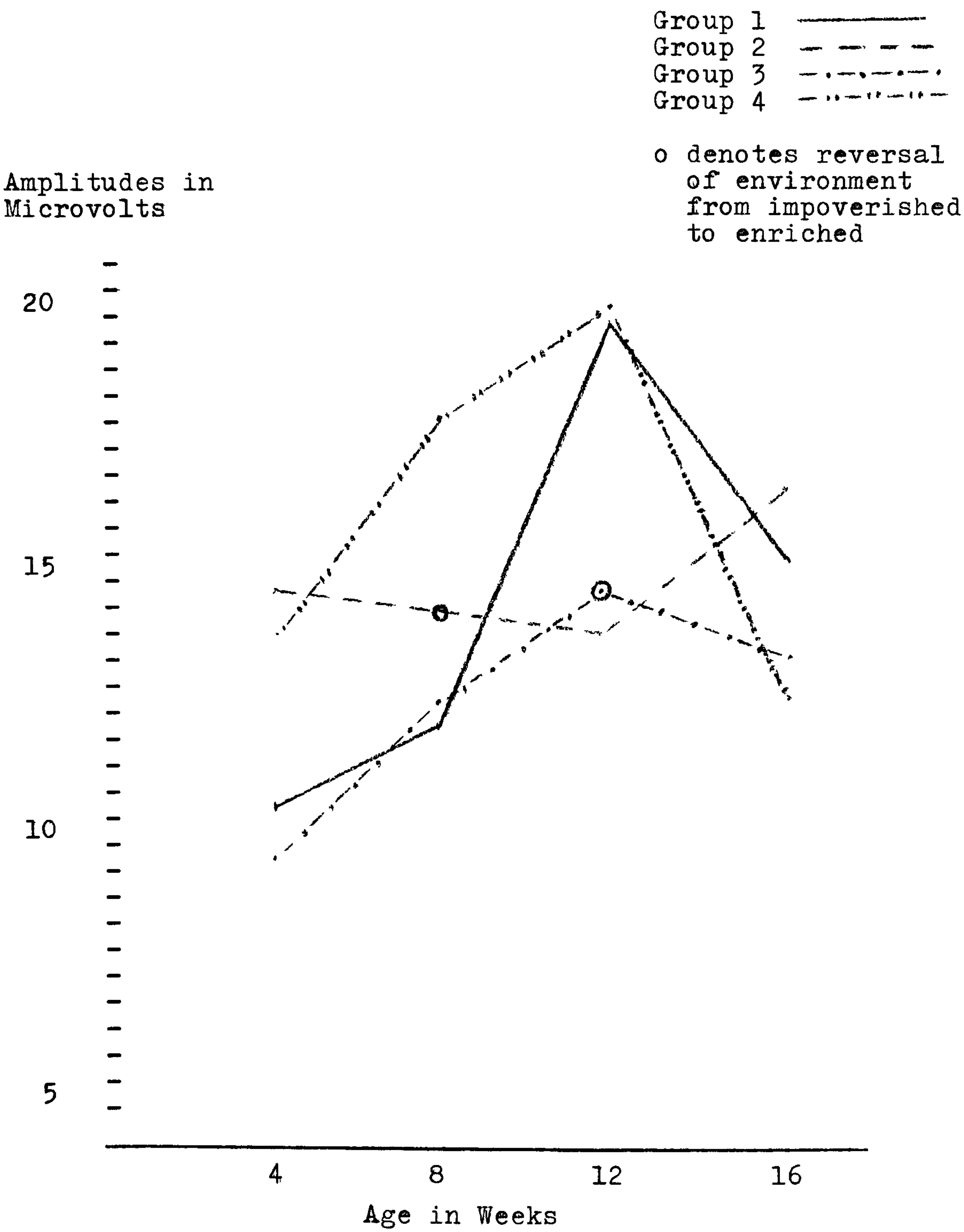

Figure 8.- Averaged Amplitudes of Photic Evoked Potentials Event Three of the Four Groups of Rats at Four Age Levels.

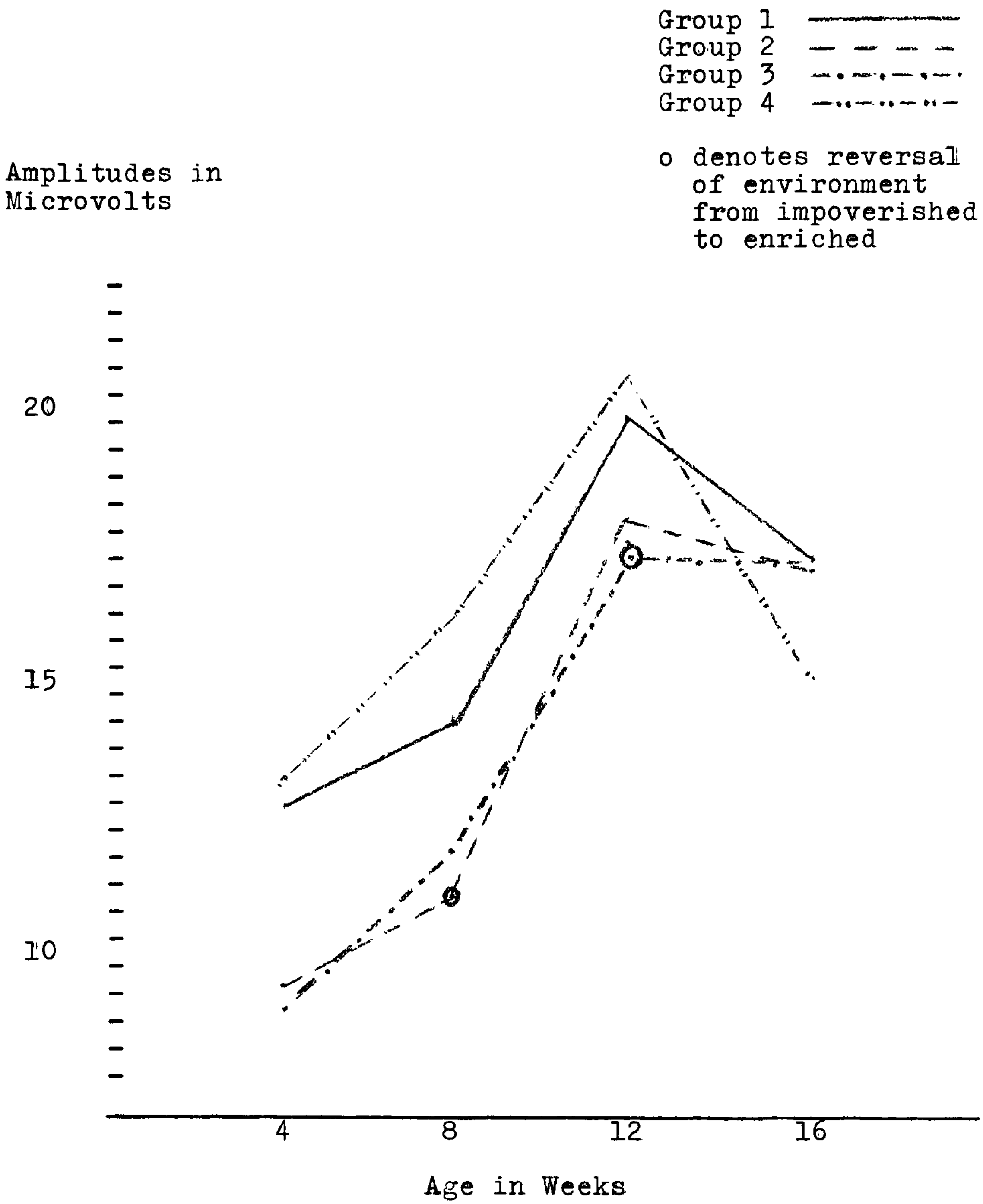

Figure 9.- Averaged Amplitudes of Photic Evoked Potentials Event Four of the Four Groups of Rats at Four Age Levels.

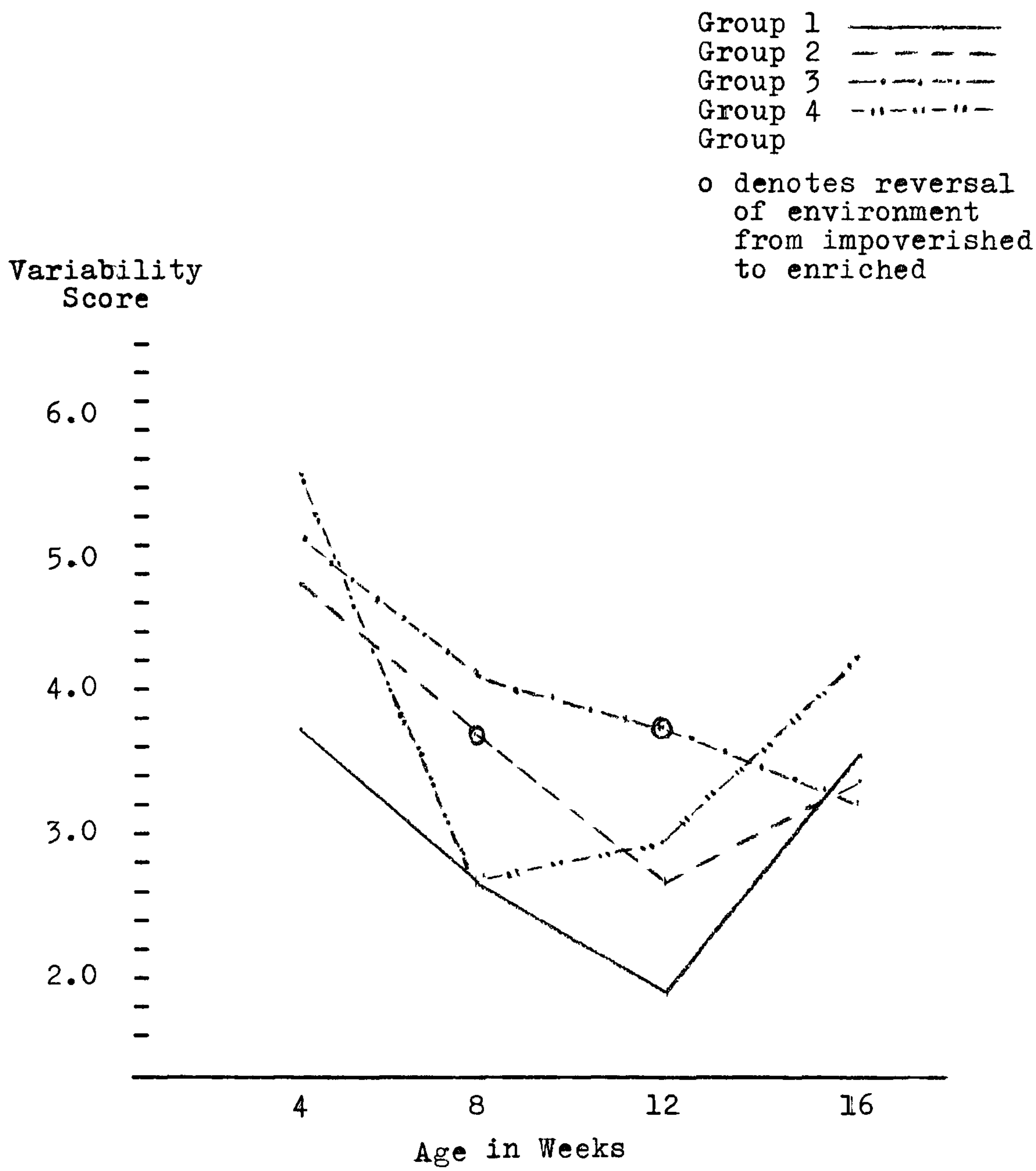

Figure 10.- Averaged Group Variability Scores of Photic Evoked Potentials of the Four Groups of Rats at Four Age Levels.

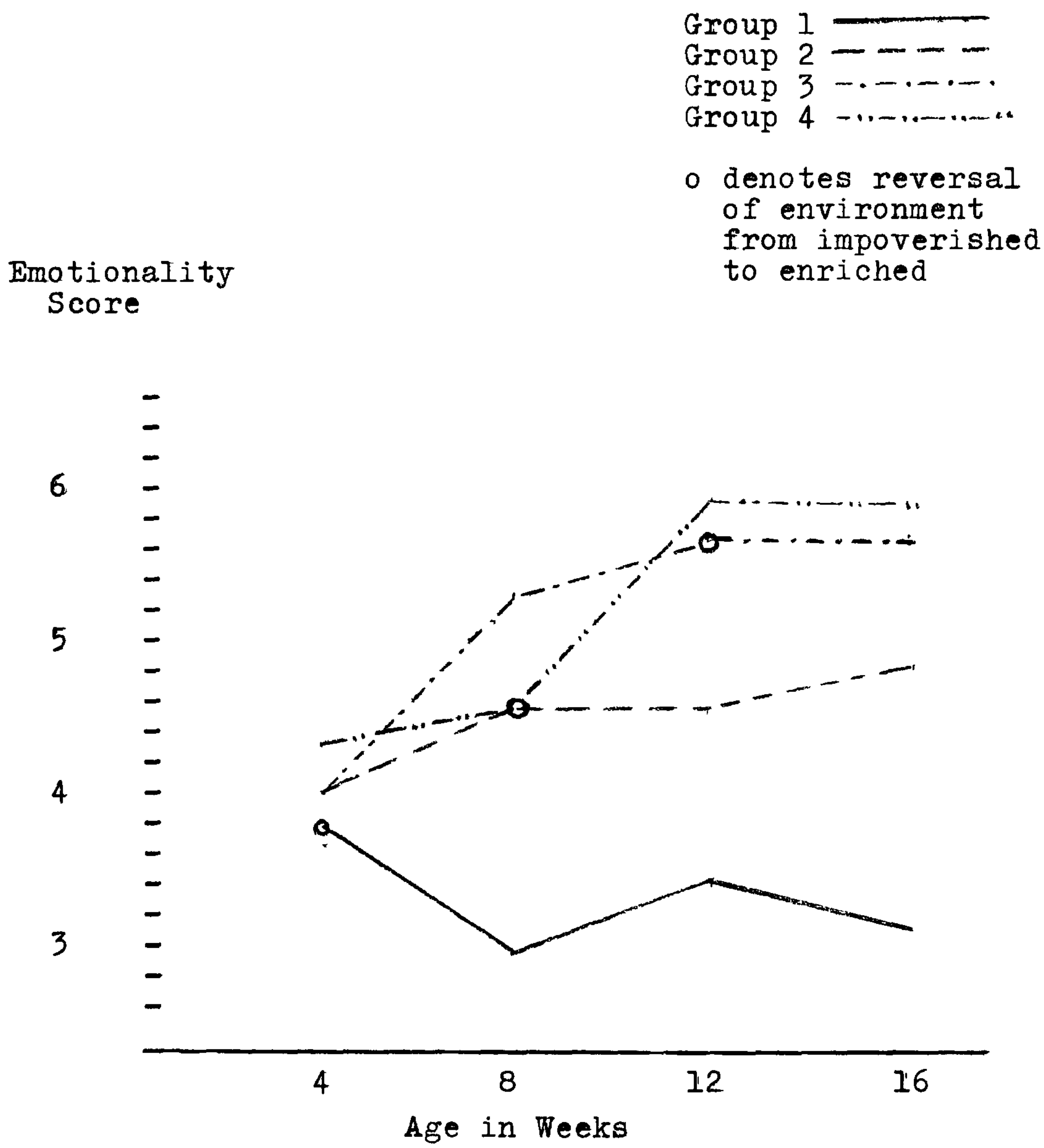

Figure 11.- Averaged Group Emotionality Scores of the Four Groups of Rats at Four Age Levels.

Table XII.-

Comparisons of Group Photic Evoked Potentials Latency of Event One, Using Scheffe's Test for Multiple Comparisons.

Comparison	Di^2	MS Di	F	P
A vs E	400	50	0.39	NS
A vs I	784	98	0.77	NS
A vs M	484	60.5	0.47	NS
E vs I	64	8	0.06	NS
E vs M	4	0.5	0.00	NS
I vs M	36	4.5	0.04	NS
B vs F+J+N	324	6.8	0.05	NS
C vs G	1	0.13	0.00	NS
C vs K+O	196	8.17	0.06	NS
G vs K+O	256	10.67	0.08	NS
D vs H	121	15.1	0.12	NS
D vs L	169	21.13	0.17	NS
D vs P	9	1.1	0.01	NS
H vs L	4	0.5	0.00	NS
H vs P	64	8	0.06	NS
L vs P	100	12.5	0.10	NS
T1 vs T2	900	112.5	0.88	NS
T1 vs T3	1764	220.5	1.73	NS
T1 vs T4	3136	392	3.07	NS
T2 vs T3	144	18	0.14	NS
T2 vs T4	676	84.5	0.66	NS
T3 vs T4	196	24.5	0.19	NS

The Error Term = 127.54

Table XIII.-

Comparisons of Group Photic Evoked Potentials Latency of Event ~~One~~ Two, Using Scheffe's Test for Multiple Comparisons.

Comparison	Di^2	MS Di	F	P
A vs E	5625	703.1	1.85	NS
A vs I	1089	136.13	0.36	NS
A vs M	225	28.13	0.07	NS
E vs I	1764	220.5	0.58	NS
E vs M	3600	450	1.19	NS
I vs M	324	40.5	0.11	NS
B vs F+J+N	15129	315.2	0.83	NS
C vs G	64	8	0.02	NS
C vs K+O	13225	551	1.45	NS
G vs K+O	17161	715.0	1.89	NS
D vs H	3025	378.1	1.00	NS
D vs L	4900	612.5	1.61	NS
D vs P	2304	288	0.76	NS
H vs L	225	28.1	0.07	NS
H vs P	49	6.1	0.02	NS
L vs P	484	60.5	0.16	NS
T1 vs T2	54756	6844.5	18.10	.05
T1 vs T3	21025	2628.13	6.93	NS
T1 vs T4	21609	2701.1[illegible]	7.12	NS
T2 vs T3	7921	990.1	2.61	NS
T2 vs T4	7569	946.1	2.49	NS
T3 vs T4	4	0.5	0.00	NS

The error term = 379.26

Table XIV.-

Comparisons of Group Photic Evoked Potentials Latency of Event Three, Using Scheffe's Test for Multiple Comparisons.

Comparison	Di^2	MS Di	F	P
A vs E	13456	1682	1.90	NS
A vs I	39204	4900	5.54	NS
A vs M	10000	1250	1.41	NS
E vs I	6724	841	0.95	NS
E vs M	256	32	0.04	NS
I vs M	9604	1201	1.36	NS
B vs F+J+N	113569	2366	2.68	NS
C vs G	144	18	0.02	NS
C vs K+O	11664	486	0.55	NS
G vs K+O	17424	726	0.82	NS
D vs H	3025	378	0.43	NS
D vs L	2304	288	0.33	NS
D vs P	1600	200	0.23	NS
H vs L	49	6	0.01	NS
H vs P	225	28	0.03	NS
L vs P	64	8	0.01	NS
T1 vs T2	74529	9316	10.53	.05
T1 vs T3	103684	12961	14.65	.05
T1 vs T4	156025	19503	22.05	.05
T2 vs T3	2401	300	0.34	NS
T2 vs T4	14884	1861	2.10	NS
T3 vs T4	5329	666	o.75	NS

The error term = 884.43

Table XV.-

Comparisons of Group Photic Evoked Potentials Latency of Event Four, Using Scheffe's Test for Multiple Comparisons.

Comparison	Di^2	MS Di	F	P
A vs E	4096	512	0.53	NS
A vs I	18225	2278	2.34	NS
A vs M	19881	2485	2.55	NS
E vs I	5041	630	0.65	NS
E vs M	5929	741	0.76	NS
I vs M	36	5	0.00	NS
B vs F+J+N	75076	1564	1.60	NS
C Vs G	225	28	0.03	NS
C vs K+O	28900	1204	1.23	NS
G vs K+O	40000	1666	1.71	NS
D vs H	16641	2080	2.13	NS
D vs L	484	61	0.06	NS
D vs P	1225	153	0.16	NS
H vs L	11449	1431	1.47	NS
H vs P	8836	1105	1.13	NS
L vs P	169	21	0.02	NS
T1 vs T2	69169	8646	8.87	.10
T1 vs T3	45369	5671	5.82	NS
T1 vs T4	229441	28680	29.41	.05
T2 vs T3	2500	312	0.32	NS
T2 vs T4	46656	5832	5.98	NS
T3 vs T4	70756	8845	9.07	.05

The error term = 975.13

Table XVI.-

Comparisons of Group Photic Evoked Potentials Amplitude of Event One, Using Scheffe's Test for Multiple Comparisons.

Comparison	Di^2	MS Di	F	P
A vs E	59.3	7.41	0.44	NS
A vs I	32.5	4.06	0.24	NS
A vs M	53.3	6.66	0.39	NS
E vs I	4	0.50	0.03	NS
E vs M	0.2	0.02	0.00	NS
I vs M	2.6	0.32	0.02	NS
B vs F+J+N	676.0	14.08	0.83	NS
C vs G	125.4	15.68	0.93	NS
C vs K+O	13.69	0.57	0.03	NS
G vs K+O	349.7	14.57	0.86	NS
D vs H	~~125.4~~ 275.6	~~15.68~~ 34.45	~~0.93~~ 2.04	NS
D vs L	~~13.7~~ 1.96	0.25	0.01	NS
D vs P	327.6	40.95	2.42	NS
H vs L	324	40.50	2.39	NS
H vs P	2.25	0.28	0.02	NS
L vs P	380.3	47.53	2.81	NS
T1 vs T2	15.21	1.90	0.11	NS
T1 vs T3	231.0	28.88	1.71	NS
T1 vs T4	21.16	2.65	0.16	NS
T2 vs T3	127.7	15.96	0.94	NS
T2 vs T4	0.49	0.06	0.00	NS
T3 vs T4	112.4	14.1	0.83	NS

The Error Term = 16.92

Table XVII.-

Comparisons of Group Photic Evoked Potentials amplitudes of Event Two, Using Scheffe's Test for Multiple Comparisons.

Comparison	Di^2	MS di	F	P
A vs E	4.8	0.61	0.04	NS
A vs I	196.0	24.50	1.47	NS
A vs M	139.2	17.41	1.05	NS
E vs I	262.4	32.81	1.97	NS
E vs M	196.0	24.50	1.47	NS
I vs M	4.8	0.61	0.04	NS
B vs F+J+N	1528.8	31.85	1.91	NS
C vs G	0.5	0.06	0.00	NS
C vs K+O	30.3	1.26	0.01	NS
G vs K+O	16.8	0.70	0.04	NS
D vs H	84.6	10.58	0.64	NS
D vs L	12.3	1.53	0.09	NS
D vs P	151.3	18.91	1.14	NS
H vs L	161.3	20.16	1.21	NS
H vs P	9.6	1.20	0.07	NS
L vs P	249.6	31.21	1.88	NS
T1 vs T2	445.2	55.65	3.34	NS
T1 vs T3	475.2	59.41	3.57	NS
T1 vs T4	10.2	1.28	0.08	NS
T2 vs T3	0.5	0.06	0.00	NS
T2 vs T4	590.5	73.81	4.44	NS
T3 vs T4	625.0	78.13	4.70	NS

The Error Term = 16.64

Table XVIII.-

Comparisons of Group Photic Evoked Potentials Amplitudes of Event Three, Using Scheffe's Test For Multiple Comparisons.

Comparison	Di^2	MS Di	F	P
A vs E	299.3	37.41	2.08	NS
A vs I	10.9	1.36	0.08	NS
A vs M	141.6	17.70	0.98	NS
E vs I	424.4	53.05	2.94	NS
E vs M	29.2	3.65	0.20	NS
I vs M	231.0	28.88	1.60	NS
B vs F+J+N	1232.0	25.67	1.42	NS
C vs G	372.5	46.56	2.58	NS
C vs K+O	225.0	9.38	0.52	NS
G vs K+O	557.0	23.21	1.29	NS
D vs H	47.6	5.95	0.33	NS
D vs L	12.3	1.53	0.08	NS
D vs P	53.3	6.66	0.37	NS
H vs L	108.2	13.52	0.75	NS
H vs P	201.6	25.21	1.40	NS
L vs P	14.44	1.81	0.10	NS
T1 vs T2	231.2	26.65	1.48	NS
T1 vs T3	404.0	50.50	2.80	NS
T1 vs T4	800.9	100.11	5.56	NS
T2 vs T3	1204.1	150.51	8.35	.10
T2 vs T4	187.7	23.46	1.30	NS
T3 vs T4	2342.6	292.82	16.25	.05

The Error Term = 18.02

Table XIX.-

Comparisons of Group Photic Evoked Potentials Amplitudes of Event Four, Using Scheffe's Test for Multiple Comparisons.

Comparison	Di2	MS Di	F	P
A vs E	219.0	27.38	1.81	NS
A vs I	316.8	39.61	2.62	NS
A vs M	2.3	0.28	0.02	NS
E vs I	9.0	1.13	0.07	NS
E vs M	265.7	33.21	2.20	NS
I vs M	372.4	46.56	3.08	NS
B vs F+J+N	110.3	2.30	0.15	NS
C vs G	65.6	8.20	0.54	NS
C vs K+O	57.8	2.41	0.16	NS
G vs K+O	74.0	3.08	0.20	NS
D vs H	0.81	0.10	0.01	NS
D vs L	0.0	0.00	0.00	NS
D vs P	106.1	13.26	0.88	NS
H vs L	0.6	0.08	0.01	NS
H vs P	88.4	11.05	0.73	NS
L vs P	104.0	13.01	0.86	NS
T1 vs T2	1239.0	154.88	10.24	.10
T1 vs T3	1339.6	167.45	11.07	.05
T1 vs T4	10.2	1.28	0.08	NS
T2 vs T3	1.9	0.25	0.02	NS
T2 vs T4	1474.6	184.32	12.19	.05
T3 vs T4	1584.0	198.01	13.1	.05

The Error Term = 15.12

Table XX.-

Comparisons of Group Evoked Potentials Variability Scores, Using Scheffe's Test for Multiple Comparisons.

Comparison	Di^2	MS Di	F	P
A vs E	4	0.50	0.40	NS
A vs I	25	3.13	2.49	NS
A vs M	49	6.13	4.88	NS
E vs I	9	1.13	0.90	NS
E vs M	25	3.13	2.49	NS
I vs M	4	0.50	0.40	NS
B vs F+J+N	81	1.69	1.34	NS
C vs G	9	1.13	0.90	NS
C vs K+O	64	2.67	2.12	NS
G vs K+O	4	0.17	0.13	NS
D vs H	1	o.13	0.10	NS
D vs L	4	0.50	0.40	NS
D vs P	4	0.50	0.40	NS
H vs L	1	0.13	0.10	NS
H vs P	9	1.13	0.90	NS
L vs P	16	2.00	1.59	NS
T1 vs T2	64	8.00	6.37	NS
T1 vs T3	225	28.13	22.41	.05
T1 vs T4	100	12.50	9.96	.10
T2 vs T3	49	6.13	4.88	NS
T2 vs T4	4	0.50	0.40	NS
T3 vs T4	25	3.13	2.49	NS

The Error Term = 1.255

Table XXI.-

Comparisons of Group Emotionality Scores, Using Scheffe's Test for Multiple Comparisons.

Comparison	Di^2	MS Di	F	P
A vs E	1	0.13	0.01	NS
A vs I	1	0.13	0.01	NS
A vs M	4	0.5	0.04	NS
E vs I	0	0	0	NS
E vs M	1	0.13	0.01	NS
I vs M	1	0.13	0.01	NS
B vs F+J+N	441	9.19	0.81	NS
C vs G	16	2.00	0.18	NS
C vs K+O	289	12.04	1.06	NS
G vs K+O	81	3.38	0.30	NS
D vs H	36	4.5	0.40	NS
D vs L	81	10.13	0.89	NS
D vs P	100	12.50	1.10	NS
H vs L	9	1.13	0.10	NS
H vs P	16	2.00	0.18	NS
L vs P	1	0.13	0.01	NS
T1 vs T2	289	36.13	3.19	NS
T1 vs T3	729	91.13	8.05	.10
T1 vs T4	729	91.13	8.05	.10
T2 vs T3	100	12.50	1.10	NS
T2 vs T4	100	12.50	1.10	NS
T3 vs T4	0	0	0	NS

The error term = 11.32

In general, Scheffe's test indicates that, as far as enrichment factor is concerned, individual group totals at any specific age level did not differ significantly for all the criterion variables studied. However, when the group totals summed across the four age levels were compared, Scheffe's test reveals some significant differences:-

In the latency of Event Two, group one total mean latency was found to be significantly shorter than that of group two ($F = 18.1$, $p = .05$). The total mean latency of Event Three for group one was significantly shorter than those of the other three groups (Group 1 vs Group 2, $F = 10.53$, $p = .05$; Group 1 vs Group 3, $F = 14.65$, $p = .05$; Group 1 vs Group 4, $F = 22.05$, $p = .05$). Similarly, the total mean latency,summed across the four age levels, of Event Four for group one was significantly shorter than those of groups two and four (Group 1 vs Group 2, $F = 8.87$, $p = .10$; Group 1 vs Group 4, $F = 29.41$, $p = .05$). In this last event, the total mean latency for group three was also found to be statistically different from that of group four ($F = 9.07$, $p = .05$).

Sceffe's test applied to the amplitudes on the enrichment factor alone indicates that the total mean amplitude of Event Three, summed across the four age levels, of group three was significantly smaller than those of groups two and four (Group 2 vs Group 3, $F = 8.35$, $p = .10$; Group 3 vs Group 4, $F = 16.25$, $p = .05$). Similarly, when the group totals for amplitude of Event Four summed across the four age levels were compared, groups one and four had significantly larger amplitudes than groups two and three (Group 1 vs Group 2, $F = 10.24$, $p = .10$; Group 1 vs Group 3, $F = 11.07$, $p = .05$; Group 2 vs Group 4, $F = 12.19$, $p = .05$; Group 3 vs Group 4, $F = 13.10$, $p = .05$).

Scheffe's test, applied to the variability of PEP wave form on the enrichment factor alone, indicates that the total group variability score, summed across the four age levels, of group one was statistically different from thos of groups three and four (Group 1 vs Group 3, $F = 22.41$, $p = .05$; Group 1 vs Group 4, $F = 9.96$, $p = .10$). The latter two groups showed greater variability.

Similarly, Scheffe's test applied to emotionality scores on the enrichment factor indicates that while individual group comparisons at any specific age level were statistically insignificant, the total emotionality measure of group one, summed across the four age levels, was statistically different from those of groups three and four (Group 1 vs Group 3, $F = 8.05$, $p = .10$; Group 1 vs Group 4, $F = 8.05$, $p = .10$). Group one subjects were on the whole less emotional than groups three and four subjects across the four age levels.

No other comparisons were significant at the .10

level. For significant F values and the characteristics of the selected comparisons, the reader is referred to the previous chapter (p. 70-71). For PEP Event labels, refer to Figure 12. For the size of group means of PEP latencies and amplitudes, refer to Tables XXII and XXIII respectively. These two tables indicate the direction of the differences among the four groups.

Table XXII.-

Means and Standard Deviations of Photic Evoked Potential Latencies Measured in milliseconds.

Occasion[a]	Event[b]	Group 1 M	Group 1 S	Group 2 M	Group 2 S	Group 3 M	Group 3 S	Group 4[c] M	Group 4[c] S
4 Weeks	(1)	52	5.9	57	4.7	59	6.9	60	10.8
	(2)	79	14.1	98	14.8	87	19.8	83	10.6
	(3)	149	47.5	178	15.1	199	8.5	174	20.7
	(4)	244	33.8	260	45.0	278	26.7	279	19.1
8 Weeks	(1)	51	2.5	51	1.7	50	2.2	56	4.9
	(2)	78	21.5	106	24.6	79	25.0	80	12.6
	(3)	169	45.6	197	21.2	174	16.0	220	35.2
	(4)	262	8.4	283	28.3	256	24.1	315	37.4
12 weeks	(1)	54	5.5	53	3.6	54	3.9	56	1.5
	(2)	73	8.1	71	2.6	83	19.8	92	28.3
	(3)	168	19.0	165	8.5	182	5.7	181	8.5
	(4)	262	35.1	258	22.6	283	16.6	285	16.5
16 Weeks	(1)	56	1.9	58	5.3	59	2.5	56	5.1
	(2)	80	8.8	94	16.9	98	14.3	92	15.7
	(3)	173	14.7	187	6.2	185	6.7	183	19.2
	(4)	257	6.6	290	17.1	263	19.4	266	36.2

a Photic evoked potentials were recorded at one month intervals.

b For event labels, refer to Fig. 12.

c Group 1, N=4 ; Group 2, N=4 ; Group 3, N=4 ; Group 4, N=4 for the first two occasions and N=3 for occasions 12 weeks and 16 weeks.

Table **XXIII.-**

Means and Standard Deviations of Photic Evoked Potential Amplitudes Measured in microvolts.

Occasion[a]	Event[b]	Group 1		Group 2		Group 3		Group 4[c]	
		M	S	M	S	M	S	M	S
4 Weeks	(1)	7.4	2.77	5.5	2.9	6.0	2.2	5.6	3.33
	(2)	12.5	5.62	13.1	4.3	9.0	4.0	9.6	5.50
	(3)	10.2	1.62	14.6	4.5	9.4	4.3	13.2	5.23
	(4)	12.45	3.14	8.75	3.0	8.0	2.7	12.8	1.87
8 Weeks	(1)	7.35	2.17	8.9	2.4	12.6	4.7	7.1	3.69
	(2)	12.1	1.70	14.4	2.3	19.8	6.9	12.0	2.93
	(3)	11.7	5.04	14.1	1.6	12.3	4.8	17.4	5.35
	(4)	14.0	2.84	11.2	5.1	12.0	3.8	16.3	9.13
12 Weeks	(1)	9.5	4.25	6.7	1.1	9.8	4.4	8.1	2.96
	(2)	12.8	4.38	12.9	4.0	14.9	4.6	12.0	5.14
	(3)	18.5	6.81	13.7	7.3	14.5	6.2	18.7	4.69
	(4)	19.60	7.06	17.58	4.37	17.0	8.1	20.3	6.90
16 Weeks	(1)	8.2	1.80	12.4	8.2	7.9	1.8	12.7	6.43
	(2)	10.7	2.46	12.95	6.5	9.8	2.1	13.7	2.54
	(3)	14.7	3.45	16.4	5.2	13.8	3.0	12.9	1.72
	(4)	17.1	1.45	16.8	4.3	17.0	4.2	14.5	0.8

a Photic evoked potentials were recorded at one month intervals.

b For event labels, refer to Fig. 12.

c Group 1, N=4 ; Group 2, N=4 ; Group 3, N=4 ; Group 4, N=4 for occasions 4 weeks and 8 weeks, and N=3 for occasions 12 weeks and 16 weeks.

d. Trend Analysis on A x B Interaction.

Computations for trend analysis are summarized in Tables XXIV to XXXIII. As explained in the previous chapter, even in the absence of significant overall effect due to enrichment x age interactions, trend analysis was performed because it reveals statistically the shape of individual and overall profiles and the extent of similarity among the individual profiles with respect to linear, quadratic, and cubic trends. It also serves as a test of significance to compliment the figural representations, Fig. 2 to Fig.11, of the changes in group mean PEP variables and emotionality measure as a function of time.

Trend analysis for PEP latency of Event One indicates that the overall and individual group profiles were essentially quadratic. It is interesting to note that the trend for groups two and three was significantly quadratic, while the trend for groups one and four did not show a particular form. The difference in the quadratic trend, although not statistically significant, explains 98.19/136.37 or 72 % of the total variance due to AB interaction. Animals reared in the impoverished condition at first and then transferred to the enriched condition (Groups 2 and 3), therefore, showed different developmental changes in PEP latency of Event One, when compared with animals reared in a constant environment throughout the experimental period.

Table XXIV.-

Trend Analysis of Group Profiles Showing Changes in Photic Evoked Potentials Latency of Event One as a Function of Time.

Trend	Linear			Quadratic			Cubic		
	MS	F	P	MS	F	P	MS	F	P
Individual Groups :- (df = 1, 36)									
Group 1	36.45	1.68	NS	12.25	0.56	NS	6.05	0.28	NS
Group 2	8.45	0.39	NS	132.25	6.09	.05	9.80	0.45	NS
Group 3	2.45	0.11	NS	182.25	8.39	.01	33.80	1.56	NS
Group 4	1.80	0.08	NS	4.00	0.18	NS	2.45	0.11	NS
Group Differences :- (df = 3, 36)									
	9.38	0.43	NS	32.73	1.51	NS	3.35	0.15	NS
Overall :- (df = 1, 36)									
	21.01	0.97	NS	232.56	10.71	.01	42.05	1.94	NS

The error term = 21.72

$.95\ F_{(1,36)} = 4.15$; $.99\ F_{(1,36)} = 7.50$

$.95\ F_{(3,36)} = 2.89$; $.99\ F_{(3,36)} = 4.40$

Table XXV.-

Trend Analysis of Group Profiles Showing Changes in Photic Evoked Potentials Latency of Event Two as a Function of Time.

Trend	Linear			Quadratic			Cubic		
	MS	F	P	MS	F	P	MS	F	P
Individual Groups :- (df = 1, 36)									
Group 1	0.61	0.00	NS	68.06	0.27	NS	46.51	0.19	NS
Group 2	437.11	1.75	NS	217.56	0.87	NS	2010.01	8.07	.05
Group 3	238.05	0.96	NS	552.25	2.22	NS	0.20	0.00	NS
Group 4	328.05	1.32	NS	9.00	0.04	NS	168.20	0.68	NS
Group Differences :- (df = 3, 36)									
	322.91	1.30	NS	78.11	0.31	NS	619.81	2.49	NS
Overall :- (df = 1, 36)									
	35.11	0.14	NS	612.56	2.46	NS	365.51	1.47	NS

The error term = 249.10

Table XXVI.-

Trend Analysis of Group Profiles Showing Changes in Photic Evoked Potentials Latency of Event Three as a Function of Time.

Trend	Linear			Quadratic			Cubic		
	MS	F	P	MS	F	P	MS	F	P
Individual Groups :- (df = 1, 36)									
Group 1	973.01	2.58	NS	217.56	0.58	NS	132.61	0.35	NS
Group 2	11.25	0.03	NS	6.25	0.02	NS	2205.00	5.84	.05
Group 3	227.81	0.61	NS	770.06	2.04	NS	300.31	0.79	NS
Group 4	33.80	0.09	NS	1892.25	5.00	.05	3375.2	8.14	.01
Group Differences :- (df = 3, 36)									
	411.29	1.09	NS	896.71	2.37	NS	1126.78	2.98	.05
Overall :- (df = 1, 36)									
	12.01	0.03	NS	196.00	0.52	NS	2332.8	6.17	.05

The error term = 377.84

Table XXVII.-

Trend Analysis of Group Profiles Showing Changes in Photic Evoked Potentials Latency of Event Four as a Function of Time.

Trend	Linear			Quadratic			Cubic		
	MS	F	P	MS	F	P	MS	F	P
Individual Groups :- (df = 1, 36)									
Group 1	320.0	0.55	NS	506.3	0.87	NS	31.3	0.05	NS
Group 2	812.8	1.40	NS	68.1	0.12	NS	2152.8	3.70	NS
Group 3	78.0	0.13	NS	7.6	0.01	NS	1647.1	2.83	NS
Group 4	959.1	1.65	NS	2943.1	5.06	.05	1132.5	1.95	NS
Group Differences :- (df = 3, 36)									
	719.7 ~~2159.1~~	1.24	NS	814.7	1.40	NS	1485.4	2.55	NS
Overall :- (df = 1, 36)									
	10.9	0.02	NS	1080.8	1.86	NS	507.5	0.87	NS

The error term = 582.19

Table XXVIII.-

Trend Analysis of Group Profiles Showing Changes in Photic Evoked Potentials Amplitude of Event One as a Function of Time.

Trend	Linear			Quadratic			Cubic		
	MS	F	P	MS	F	P	MS	F	P
Individual Groups :- (df = 1, 36)									
Group 1	3.92	0.30	NS	1.38	0.11	NS	6.11	0.47	NS
Group 2	66.98	5.16	.05	5.29	0.41	NS	36.99	2.85	NS
Group 3	1.54	0.12	NS	72.68	5.60	.05	20.71	1.60	NS
Group 4	101.03	7.79	.01	9.46	0.73	NS	2.93	0.23	NS
Group Differences :- (df = 3, 36)									
	19.46	1.50	NS	28.04	2.16	NS	14.12	1.09	NS
Overall :- (df = 1, 36)									
	115.08	8.87	.01	4.68	0.36	NS	24.37	1.88	NS

The error term = 12.97

Table XXIX.-

Trend Analysis of Group Profiles Showing Changes in Photic Evoked Potentials Amplitude of Event Two as a Function of Time.

Trend	Linear			Quadratic			Cubic		
	MS	F	P	MS	F	P	MS	F	P
Individual Groups :- (df = 1, 36)									
Group 1	4.85	0.26	NS	2.98	0.16	NS	2.78	0.15	NS
Group 2	0.61	0.03	NS	1.69	0.09	NS	3.61	0.19	NS
Group 3	1.38	0.07	NS	253.61	13.52	.01	48.83	2.60	NS
Group 4	31.63	1.69	NS	0.46	0.02	NS	3.24	0.17	NS
Group Differences :- (df = 3, 36)									
	12.64	0.67	NS	54.15	2.89	.05	12.70	0.68	NS
Overall :-									
	0.54	0.03	NS	96.29	5.13	.05	20.35	1.08	NS

The error term = 18.76

Table XXX.-

Trend Analysis of Group Profiles Showing Changes in Photic Evoked Potentials Amplitude of Event Three as a Function of Time.

Trend	Linear			Quadratic			Cubic		
	MS	F	P	MS	F	P	MS	F	P
Indifidual Groups :- (df = 1,36)									
Group 1	82.01	3.53	NS	27.04	1.16	NS	51.20	2.20	NS
Group 2	5.41	0.23	NS	10.56	0.45	NS	1.98	0.85	NS
Group 3	47.90	2.06	NS	12.78	0.55	NS	0.95	0.04	NS
Group 4	0.03	0.00	NS	99.5	4.28	.05	3.83	0.16	NS
Group Differences :- (df = 3, 36)									
	16.69	0.72	NS	29.94	1.29	NS	13.05	0.56	NS
Overall :- (df = 1, 36)									
	85.28	3.67	NS	60.06	2.58	NS	18.82	0.81	NS

The error term = 23.25

Table XXXI.-

Trend Analysis of Group Profiles Showing Changes in Photic Evoked Potentials Amplitude of Event Four as a Function of Time.

Trend	Linear MS	Linear F	Linear P	Quadratic MS	Quadratic F	Quadratic P	Cubic MS	Cubic F	Cubic P
Individual Groups :- (df = 1, 36)									
Group 1	75.08	2.95	NS	17.02	0.67	NS	29.40	1.15	NS
Group 2	187.58	7.36	.05	10.08	0.40	NS	24.75	0.99	NS
Group 3	206.40	8.10	.01	15.41	0.60	NS	7.50	0.29	NS
Group 4	15.93	0.63	NS	86.96	3.41	NS	21.12	0.83	NS
Group Differences :- (df = 3, 36)									
	23.49	0.92 ~~1.26~~	NS ~~0.31~~	7.96	0.31	NS	1.39	0.05	NS
Overall :- (df = 1, 36)									
	414.51	16.27	.001	105.6	4.14	.05	78.61	3.09	NS

The error term = 25.48

Table XXXII.-

Trend Analysis of Group Profiles Showing Changes in Photic Evoked Potentials Variability as a Function of Time.

Trend	Linear			Quadratic			Cubic		
	MS	F	P	MS	F	P	MS	F	P
Individual Groups :- (df = 1, 36)									
Group 1	0.11	0.12	NS	7.56	8.22	.01	1.01	1.10	NS
Group 2	2.11	2.30	NS	1.56	1.70	NS	1.01	1.10	NS
Group 3	6.05	6.58	.05	0.25	0.27	NS	0.20	0.22	NS
Group 4	3.61	3.93	NS	22.56	24.52	.001	0.01	0.01	NS
Group Differences :- (df = 3, 36)									
	0.81	0.88	NS	3.52	3.82	.05	0.56	0.56	NS
Overall :- (df = 1, 36)									
	9.45	10.28	.01	23.39	23.25	.001	0.70	0.76	NS

The error term = 0.92.

Table XXXIII.-

Trend Analysis of Group Profiles Showing Changes in Emotionality as a Function of Time.

Trend	Linear			Quadratic			Cubic		
	MS	F	P	MS	F	P	MS	F	P
Individual Groups :- (df = 1, 36)									
Group 1	0.20	0.23	NS	0.25	0.29	NS	0.80	0.92	NS
Group 2	1.01	1.16	NS	0.06	0.07	NS	0.11	0.13	NS
Group 3	4.51	5.18	.05	1.56	1.79	NS	0.05	0.06	NS
Group 4	6.61	7.60	.01	0.06	0.07	NS	1.01	1.16	NS
Group Differences :- (df = 3, 36)									
	1.81	2.08	NS	0.52	0.60	NS	0.53	0.61	NS
Overall :- (df = 1, 36)									
	6.90	7.93	.01	0.39	0.45	NS	0.38	0.43	NS

The error term = 0.87

Trend analysis for Event Two latency provides no significant clue as to the ~~ahpae~~ shape of individual and overall profiles; there is some indication that the curves differed in the cubic trend, although the F value ($F = 2.49$, df = 3, 36) was not significant at the .o5 level.

In trend analysis for latency of Event Three, it should be noted that the group profiles differed significantly in the cubic trend ($F = 2.98$, $p = .05$), which explains 46.27 % of the total variance due to AB interaction. This difference is attributed to the fact that the individual profiles of groups two and four were cubic, while that of group three was quadratic. The results indicate that while the overall effect due to AB interaction was insignificant, the profiles were not entirely similar in the cubic trend.

Trend analysis for latency of Event Four suggests that the quadratic component accounted for the majority (1080.8/1599.2 or 68.8 %) of the variance due to the Age factor. Computations for the differences in group trends indicate no significant differences. When individual trends were analysed, only that of group four was found to be significantly quadratic.

Trend analysis applied to amplitude of Event One indicates that the overall trend was significantly linear ($F = 8.87$, $p = .01$); and that individual profiles were not statistically different from one another, although the trend for group three was quadratic while those of groups two and four were linear.

Trend analysis applied to amplitude of Event Two indicates that the overall trend was significantly quadratic ($F = 5.13$, $p = .05$); and that the individual profiles differed significantly in the quadratic trend ($F = 2.89$, $p = .05$), which explains 162.44/238.48 or 68.11 % of the total variation due to AB interaction.

In trend analysis for amplitude of Event Three, there was no clear indication of profile forms except in group four which showed a quadratic trend, and there were no significant differences among the profiles in the three trend components.

Trend analysis for amplitude of Event Four indicates that the overall trend was linear ($F = 16.27$, $p = .001$), but with quadratic tencies ($F = 4.14$, $p = .05$). The individual trends of groups two and three were also linear. It should be noted that there were no significant differences among the profiles of the four experimental groups, indicating that they were statistically similar in shape.

Trend analysis applied to variability of PEP configuration indicates that the overall trend of the profiles was quadratic ($F = 23.25$, $p = .001$) with linear tendencies ($F = 10.28$, $p = .01$). It should be noted that the group profiles differed significantly in the quadratic trend ($F = 3.82$, $p = .05$), which explains 72.7 % of the total variance attributed to the AB interaction effect. This difference was due to the fact that, while the profiles for groups one and four were quadratic, the profile for group three was significantly linear.

Trend analysis applied to emotionality scores indicates that the overall trend due to the main effect of Age was significantly linear ($F = 7.93$, $p = .01$), which is mainly explained by the linearity of group three and group four profiles. The differences among the individual profiles, however, were not significant in any of the three trend components.

e. One Way Analysis of Variance on Data Studied at each Age Level.

Statistical analysis results thus far presented deal with Enrichment and Age factors and their interaction. This section presents results performed on the enrichment effect alone. Analysis on the PEP variables and emotionality measure was to compliment Scheffe's tests described earlier, while analysis on the remaining behavioral variables was to serve as statistical basis in testing the specific null hypotheses.

The results of the tests of significance are summarized in Tables XXXIV to XLIX.

i). PEP Data. For each of four events studied at each of four age levels, there were no significant differances in PEP latency observed among the four groups, except that on one occasion (4 weeks), the latencies of Event Four of groups one and two were found to be significantly shorter than those of groups three and four, ($F=3.91$, $p = .05$). Since only one out of sixteen comparisons of the groups was found to be significant, this difference could be attributed to chance alone. However, except for a few inconsistencies in the dats, the latencies of the enriched groups were found to be shorter than those of the impoverished groups. Thus, although only one of the statistical comparisons on the latencies of PEP reached

Table XXXIV.-

Analysis of Variance of Photic Evoked Potential Latencies[a] of Event One in the Four Groups of Rats at Four Occasions, Using the Completely Randomized Design.

Occasion[b]	Source	SS	df	ms	F[c]	p
Four Weeks	Total	818.0	15			
	Between Gps.	152.0	3	50.7	0.91	insig.
	Within Gps.	666.0	12	55.5		
Eight Weeks	Total	195.8	15			
	Between Gps.	80.8	3	26.9	2.81	insig.
	Within Gps.	115.0	12	9.6		$<.10$
Twelve Weeks	Total	198.4	14			
	Between Gps.	19.2	3	6.4	0.39	insig.
	Within Gps.	179.2	11	16.3		
Sixteen Weeks	Total	194.9	14			
	Between Gps.	27.8	3	9.3	0.61	insig.
	Within Gps.	167.2	11	15.2		

a Photic Evoked Potential Latencies are measured in milliseconds following the onset of photic stimulation.

b The number of weeks signifies the age of the subjects when the photic evoked potentials were recorded.

c Observed values of χ_r^2 in the Friedman Two-way Analysis of Variance by Ranks for the Four Occasions are : Four Weeks χ_r^2=3,2, p=.40; Eight Weeks χ_r^2=4.3, p=.28; Twelve Weeks χ_r^2=0.8, p=.90; Sixteen Weeks χ_r^2=2.5, p=51.

Table XXXV.-

Analysis of Variance of Photic Evoked Potential Latencies[a] of Event Two in the Four Groups of Rats at Four Occasion, Using the Completely Randomized Design.

Occasion[b]	Source	SS	df	ms	F[c]	p
Four Weeks	Total	3545	15			
	Between Gps.	789	3	263.1	1.15	insig.
	Within Gps.	2756	12	229.7		
Eight Weeks	Total	7764	15			
	Between Gps.	2207	3	735.6	1.59	insig.
	Within Gps.	5557	12	463.1		
Twelve Weeks	Total	3982	14			
	Between Gps.	982	3	327.4	1.20	insig.
	Within Gps.	3000	11	272.7		
Sixteen Weeks	Total	2891	14			
	Between Gps.	685	3	228.4	1.14	insig.
	Within Gps.	2206	11	200.5		

a Photic Evoked Potential Latencies are measured in milliseconds following the onset of photic stimulation.

b The number of weeks signifies the age of the subjects when the photic evoked potentials were recorded.

c Observed values of χ_r^2 in the Friedman Two-way analysis of variance by ranks for the four occasions are : Four Weeks χ_r^2=1.9, p=.65; Eight Weeks χ_r^2=3.6, p=.36; Twelvw Weeks χ_r^2=5.8, p=.15 ; Sixteen Weeks χ_r^2=4.9, p=.20.

Table XXXVI.-

Analysis of Variance of Photic Evoked Potential Latencies[a] of Event Three in the Four Groups of Rats at Four Occasions, Using the Completely Randomized Design.

Occasion[b]	Source	SS	df	ms	F[c]	p
Four Weeks	Total	13908	15			
	Between Gps.	4953	3	1650.9	2.21	insig.
	Within Gps.	8955	12	746.3		>.10
Eight Weeks	Total	18622	15			
	Between Gps.	6533	3	2184.4	2.17	insig.
	Within Gps.	12069	12	1005.8		>.10
Twelve Weeks	Total	2418	14			
	Between Gps.	868	3	289.2	2.05	insig.
	Within Gps.	1550	11	140.9		>.10
Sixteen Weeks	Total	2094	14			
	Between Gps.	452	3	150.8	1.01	insig.
	Within Gps.	1641	11	149.2		>.20

a Photic Evoked Potential Latencies are measured in Milliseconds following the onset of photic stimulation.

b The number of weeks signifies the age of the subjects when the photic evoked potentials were recorded.

c Observed values of χ_r^2 in the Friedman Two-way Analysis of Variance by Ranks for the four occasions are : Four Weeks χ_r^2 =3.2, p=0.40 ; Eight Weeks χ_r^2 =5.1, p=0.19 ; Twelve Weeks χ_r^2 =5.8, p=0.13; Sixteen Weeks χ_r^2 =3.4, p=0.37.

Table XXXVII.-

Analysis of Variance of Photic Evoked Potential Latencies[a] of Event Four in the Four Groups of Rats at Four Occasions, Using the Completely Randomized Design.

Occasion[b]	Source	SS	df	ms	F[c]	p
Four Weeks	Total	16057	15			
	Between Gps.	3326	3	1108.5	1.04	insig.
	Within Gps.	12731	12	1061.0		
Eight Weeks	Total	16934	15			
	Between Gps.	8365	3	2788.4	3.91	$<.05$
	Within Gps.	8569	12	714.0		
Twelve Weeks	Total	8612	14			
	Between Gps.	2003	3	667.6	1.11	insig.
	Within Gps.	6610	11	600.9		
Sixteen Weeks	Total	7167	14			
	Between Gps.	2416	3	805.5	1.87	insig.
	Within Gps.	4751	11	431.9		

a Photic Evoked Potential Latencies are measured in milliseconds following the onset of photic stimulation.

b The number of weeks signifies the age of the subjects when the photic evoked potentials were recorded.

c Observed values of χ_r^2 in the Friedman Two-way analysis of variance by ranks for the four occasions are : Four Weeks $\chi_r^2=2.7$, $p=.50$; Eight Weeks $\chi_r^2=3.4$, $p=.37$; Twelve Weeks $\chi_r^2=3.9$, $p=.32$; Sixteen Weeks $\chi_r^2=5.4$, $p=.16$.

significance, the differences between more early enriched groups and the late or no enrichment groups tend to be in the same direction, with the former shorter than the latter. Mean latencies for all four occasions (age levels) are summarized in table XXII.

In the analysis of PEP amplitude, no significant differences were found among the four groups studied at four age levels. Mean amplitudes are summarized in Table XXIII.- In general, group four subjects who received no enrichment, showed the largest amplitudes, and amplitudes of group one, which was enriched throughout the experiment, were slightly larger than those of groups two and three, whose environment was reversed during the experiment.

In the analysis of wave form variability, one significant difference out of four comparisons was found (Occasion one, $F = 4.46$, $p = .05$). Using Duncan's multiple range test, it was found that the significance was attributed to the greater variability of group three animals when compared with groups one and four.

ii). Behavioral tests Data. Means and standard deviations of the scores are summarized in Table L.

In brightness discrimination, the four groups did not differ significantly, although group one subjects appears to be better in this 'problem solving' performance, the difference approaching significance ($F= 2.6$, $p= .10$).

Table XXXVIII.-

Analysis of Variance of Photic Evoked Potential[a] Amplitudes of Event One in the Four Groups of Rats at Four Occasions, Using the Completely Randomized Design.

Occasion[b]	Source	SS	df	ms	F[c]	p
Four Weeks	Total	104.9	15			
	Between Gps.	9.5	3	3.16	0.40	insig.
	Within Gps.	95.4	12	7.95		
Eight Weeks	Total	216.6	15			
	Between Gps.	76.9	3	25.62	2.20	insig.
	Within Gps.	139.7	12	11.64		
Twelve Weeks	Total	157.2	14			
	Between Gps.	24.4	3	8.12	0.67	insig.
	Within Gps.	132.8	11	12.08		
Sixteen Weeks	Total	377.9	14			
	Between Gps.	75.7	3	25.25	0.92	insig.
	Within Gps.	302.2	11	27.47		

a Photic Evoked Potential Amplitudes are measured in microvolts.

b The number of weeks signifies the age of the subjects when the photic evoked potentials were recorded.

c Observed values of χ_r^2 in the Friedman Two-way analysis of variance by ranks for the four occasions are : Four Weeks $\chi_r^2=2.0$, $p=.61$; Eight Weeks $\chi_r^2=2.7$, $p=.51$; Twelve Weeks $\chi_r^2=2.7$, $p=.51$; Sixteen Weeks $\chi_r^2=1.9$, $p=.65$.

Table XXXIX.-

Analysis of Variance of Photic Evoked Potential[a] Amplitudes of Event Two in the Four Groups of Rats at Four Occasion, Using the Completely Randomized Design.

Occasion[b]	Source	SS	df	ms	F[c]	p
Four Weeks	Total	337.9	15			
	Between Gps.	50.2	3	16.74	0.70	insig.
	Within Gps.	287.7	12	23.98		
Eight Weeks	Total	356.6	15			
	Between Gps.	162.0	3	53.99	3.33	insig.
	Within Gps.	194.6	12	16.21		.10
Twelve Weeks	Total	239.2	14			
	Between Gps.	16.7	3	5.55	0.27	insig.
	Within Gps.	222.5	11	20.23		
Sixteen Weeks	Total	208.34	14			
	Between Gps.	37.84	3	12.61	0.81	insig.
	Within Gps.	170.50	11	15.50		

a Photic Evoked Potential Amplitudes are measured in microvolts.

b The number of weeks signifies the age of the subjects when the photic evoked potentials were recorded.

c Observed values of χ_r^2 in the Friedman Two-way analysis of variance by ranks for the four occasions are : Four Weeks $\chi_r^2=3.9$, $p=.32$; Eight Weeks $\chi_r^2=4.5$, $p=.24$; Twelve Weeks $\chi_r^2=2.1$, $p=.65$; Sixteen Weeks $\chi_r^2=2.3$, $p=.53$.

Table XL.-

Analysis of Variance of Photic Evoked Potential[a] Amplitudes of Event Three in the Four Groups of Rats at Four Occasions, Using the Randomized Design.

Occasion[b]	Source	SS	df	ms	F[c]	p
Four Weeks	Total	275.0	15			
	Between Gps.	71.0	3	23.67	1.39	insig.
	Within Gps.	204.0	12	17.00		
Eight Weeks	Total	317.5	15			
	Between Gps.	78.2	3	26.06	1.31	insig.
	Within Gps.	239.3	12	19.95		
Twelve Weeks	Total	535.8	14			
	Between Gps.	77.0	3	25.67	0.62	insig.
	Within Gps.	458.8	11	41.71		
Sixteen Weeks	Total	175.9	14			
	Between Gps.	24.8	3	8.25	0.60	insig.
	Within Gps.	151.2	11	13.74		

a Photic Evoked Potential Amplitudes are measured in microvolts.

b The number of weeks signifies the age of the subjects when the evoked potentials were recorded.

c Observed values of χ_r^2 in the Friedman Two-way analysis of variance by ranks for the 4 occasions : Four Weeks $\chi_r^2=3.0$, $p=.43$; Eight Weeks $\chi_r^2=1.5$, $p=.75$; Twelve Weeks $\chi_r^2=3.3$, $p=.39$; Sixteen Weeks $\chi_r^2=2.1$, $p=.65$.

Table XLI.-

Analysis of Variance of Photic Evoked Potential[a] Amplitudes of Event Four in the Four Groups of Rats at Four Occasions, Using the Completely Randomized Design.

Occasion[b]	Source	SS	df	ms	F[c]	p
Four Weeks	Total	162.8	15			
	Between Gps.	74.1	3	24.7	3.34	insig.
	Within Gps.	88.7	12	7.4		$<.10$
Eight Weeks	Total	459.1	15			
	Between Gps.	64.0	3	21.3	0.65	insig.
	Within Gps.	395.1	12	32.9		
Twelve Weeks	Total	524.4	14			
	Between Gps.	26.9	3	9.0	0.20	insig.
	Within Gps.	497.4	11	45.2		
Sixteen Weeks	Total	132.5	14			
	Between Gps.	15.1	3	5.0	0.47	insig.
	Within Gps.	117.4	11	10.7		

a Photic Evoked Potential Amplitudes are Measured in microvolts.

b The number of weeks signifies the age of the subjects when the photic evoked potentials were recorded.

c Observed values of χ_r^2 in the Friedman Two-way Analysis of Variance by Ranks for the four occasions are : Four Weeks χ_r^2 =9.6 , p=.01 ; Eight Weeks χ_r^2=2.6, p=.52 ; Twelve Weeks χ_r^2 =1.5, p=.75; Sixteen Weeks χ_r^2=1.7,p=.70.

Table XLII.-

Analysis of variance of Variability Scores[a] in the Four Groups of Rats at Four Occasions, Using the Completely Randomized Design.

Occasion[b]	Source	SS	df	ms	F[c]	p
Four Weeks	Total	13.8	15			
	Between Gps.	7.3	3	2.42	4.46	$<.05$
	Within Gps.	6.5	12	0.54		
Eight Weeks	Total	19.44	15			
	Between Gps.	5.19	3	1.73	1.46	insig.
	Within Gps.	14.25	12	1.19		
Twelve Weeks	Total	20.93	14			
	Between Gps.	6.77	3	2.26	1.75	insig.
	Within Gps.	14.16	11	1.29		
Sixteen Weeks	Total	15.33	14			
	Between Gps.	2.17	3	0.72	0.60	insig.
	Within Gps.	13.16	11	1.20		

a Variability scores of Averaged Evoked Potential configuration were obtained from a rating scale shown in Appendix 10.

b The number of weeks denotes the age of the subjects when the evoked potentials were recorded.

c Observed values of χ_r^2 in the Friedman Two-way analysis of variance by ranks for the four occasions are : Four Weeks $\chi_r^2 = 5.5$, p=.16; Eight Weeks $\chi_r^2 = 2.5$, p=.52; Twelve Weeks $\chi_r^2 = 5.1$, p=.19; Sixteen Weeks $\chi_r^2 = 3.4$, p=.39.

Table XLIII.-

Comparison of mean Variability Scores in the Four Groups of Rats at Four Weeks Old, Using the Duncan's Multiple-Range Test For Nearly Equal Numbers.

Group	M	N	Difference of Means[c]		
			Group 2	Group 3	Group 4
1	3.75	4	1.00[a]	1.75[b]	0.00[a]
2	2.75	4		0.75[a]	1.00[a]
3	2.00	4			1.75[b]
4	3.75	4			

a Insignificant.

b Significant ($p = .05$).

c The means are ranked in the order of Groups 3, 2, 1 or 4. To determine the significance of a difference between means, its value is compared with the following minimum mean differences at ($p = .05$) for the given range of comparisons (k) :

$k = 2$, R_2 (minimum difference of means)= 1.1323
$k = 3$, $R_3 = 1.1839$
$k = 4$, $R_4 = 1.2172$

where the R values were obtained by multiplying the significant studentized range at ($p = .05$) for the different ranges of means by the standard error of the means. The standard error of the means was derived by : $\sqrt{\frac{\text{ms within (from Table XLII)}}{\text{n (per group)}}}$ and was equal to 0.3674.

Table XLIV.-

Analysis of Variance of Brightness Discrimination Scores[a] in the Four Groups of Rats, Using the Completely Randomized Design.

Source	SS	df	ms	F[b]	p
Total	891.75	15			
Between Groups	351.25	3	117.08	2.60	$<.10$
Within Groups	540.50	12	45.04		insig.

a The scores were obtained from a black-white brightness discrimination apparatus when the subjects were eight weeks old. Each score represents the total number of trials required by a subject to reach a criterion performance of eight consecutive correct responses out of ten trials.

b The observed value of χ_r^2 in the Friedman Two-way analysis of variance by ranks is :
Eight Weeks $\chi_r^2 = 3.98$, $p=.32$.

Table XLV.-

Analysis of Variance of Avoidance Learning Scores[a] Obtained in the Four Groups of Rats, Using the Completely Randomized Design.

Source	SS	df	ms	F[b]	p
Total	18359.3	14			
Between Groups	1186.2	3	395.39	0.25	insig.
Within Groups	17173.1	11	1561.20		

a The scores were obtained on an avoidance conditioning apparatus : the Shuttle Box, when the subjects were twelve weeks old. Each score represents the total number of trials required by a subject to reach a criterion performance of nine consecutive correct avoidance responses out of ten trials.

b The observed value of χ_r^2 in the Friedman Two-way analysis of variance by ranks is :
Twelve Weeks $\chi_r^2 = 1.2$, $p = .80$.

Table XLVI.-

Analysis of Variance of Operant Conditioning Scores[a] in the Four Groups of Rats, Using the Completely Randomized Design.

Source	SS	df	ms	F[b]	p
Total	5478.0	14			
Between Groups	3055.5	3	1018.5	4.62	$<.05$
Within Groups	2422.5	11	220.22		

a The scores were obtained on a version of the Skinner Box when the subjects were sixteen weeks old. Each score represents the total number of lever depressions made by a subject in one hour.

b Observed values of χ^2_r in the Friedman Two-way analysis of variance by ranks for the 4.th occasion are : Sixteen Weeks : $\chi^2_r = 5.8$, $p = .11$.

Table XLVII.-

Comparison of Mean Operant Conditioning Scores in the Four Groups of Rats, Using the Duncan's Multiple-Range Test for Nearly Equal Ns.

Group	M	N	Difference of Means[c] Group 2	Group 3	Group 4
1	10.25	4	23.25[a]	28.50[b]	5.25[a]
2	33.50	4		5.25[a]	28.50[b]
3	38.75	4			33.75[b]
4	5.00	3			

a insignificant.

b significant ($p \leq .05$).

c The means are ranked in the order of Groups 4, 1, 2, 3. To determine the significance of a difference between means, its value is compared with the following minimum mean differences (R) for the given range of comparisons (k) :

$$k = 2, \quad R_2 = 24.038$$
$$k = 3, \quad R_3 = 25.143$$
$$k = 4, \quad R_4 = 25.810$$

where the R values were obtained by multiplying the significant studentized ranges at the ($p = .05$) for the different ranges of means by the standard error of the means. The standard error of the means was derived by : $\sqrt{\frac{\text{ms within (from Table XLVI)}}{\text{harmonic mean of Gp. Ns.}}}$ and was equal to 7.72.

Table XLVIII.-

Analysis of Variance of Activity Scores[a] obtained in the Four Groups of Rats, Using the Completely Randomized Design.

Source	SS	df	ms	F[b]	p
Total	60.59	14			
Between Groups	8.94	3	2.98	0.63	insig.
Within Groups	51.65	11	4.70		

a The scores were obtained on an activity platform when the subjects were sixteen weeks old. Each score represents the total number of body movements made by the subject in one hour, divided by 100.

b The observed value of χ_r^2 in the Friedman Two-way analysis of variance by ranks is :
Sixteen Weeks $\chi_r^2 = 1.28$, $p=.78$.

Table XLIX.-

Analysis of Variance of Emotionality Scores[a] in the Four Groups of Rats at Four Occasions, Using the Completely Randomized Design.

Occasion[b]	Source	SS	df	ms	F[c]	p
Four Weeks	Total	28.0	15			
	Between Gps.	0.5	3	0.17	0.07	insig.
	Within Gps.	27.5	12	2.29		
Eight Weeks	Total	85.44	15			
	Between Gps.	10.69	3	3.56	0.57	insig.
	Within Gps.	74.75	12	6.23		
Twelve Weeks	Total	58.93	14			
	Between Gps.	11.27	3	3.76	0.87	insig.
	Within Gps.	47.66	11	4.33		
Sixteen Weeks	Total	30.93	14			
	Between Gps.	13.77	3	4.59	2.94	$<.10$
	Within Gps.	17.16	11	1.56		insig.

a The scores were obtained from an Emotionality Rating Scale shown in Appendix 8.

b The number of Weeks signifies the age of the subjects when the rating was performed.

c Observed values of χ_r^2 in the Friedman Two-way analysis of variance by ranks for the four occasions are : Four Weeks χ_r^2=1.0, p=.90; Eight Weeks χ_r^2=1.6, p=.75; Twelve Weeks χ_r^2=4.1, p=.28; Sixteen Weeks χ_r^2=5.8, p=.11.

Table L.-

Means of Various Behavioral Measures at Specific Age Levels.

Measure	Group 1[a]	Group 2	Group 3	Group 4
Emotionality[b]				
4 weeks	3.8	4.0	4.0	4.3
8 weeks	3.0	4.5	5.3	4.5
12 weeks	3.5	4.5	5.5	5.7
16 weeks	3.3	4.8	5.5	5.7
Brightness[c] Discrimination				
8 weeks	36.5	46.0	49.3	43.8
Avoidance[d]				
12 weeks	105.5	98.8	122.3	111.3
Activity[e]				
16 weeks	1.3	3.0	3.1	2.9
Operant[f] Conditioning				
16 weeks	10.3	33.5	38.8	5.0

a Group 1, N=4; Group 2, N=4; Group 3, N=4; Group 4, N=4 at 4 and 8 weeks, and N=3 at 12 and 16 weeks.

b Higher Score indicates greater emotionality.

c Higher Score indicates greater error performance.

d Higher Score indicates greater error rate.

e Higher Score indicates greater activity.

f Higher score indicates greater number of lever-pressing responses.

In avoidance learning, the four groups again did not differ significantly.

In operant conditioning, the four groups differed significantly ($F = 4.62$, $p = .05$). Group two and group three subjects, whose environment was reversed from the impoverished condition to the enriched condition, were more active in lever pressing for food reward at this final stage of testing (16 weeks of age).

Although there were no significant differences among the groups in activity, group two and group three subjects again showed signs of greater activity.

There appears to be little differences in emotional reactivity when comparing the enriched and impoverished animals, except on the last occasion at sixteen weeks of age, when the difference approached significance ($F = 2.94$, $p \leq .10$). From Table L, however, it should be noted that enriched animals were,on the whole, less emotional.

f. Summary of the Tests of Significance.

In view of the results presented in the previous five section, the specific hypotheses ~~1 to 1.9~~ 1.1 to 1.9 must be accepted. Considering the overall results, the factor of age seems to have played a more important role than enrichment effects on the measurable changes in PEP variables. When only the enrichment factor is considered, there are some statistical indications, based primarily on the results of Scheffe's tests, that enrichment at an earlier age was accompanied by a ~~lengthening~~ shortening of PEP latencies, a reduction of PEP amplitudes, and a decrease in PEP wave form variability.

Based on the results presented in section e on the statistical analysis of behavioral data, specific null hypotheses 2.1, 2.2, 2.4, and 2.5 (as stated in p. 75) cannot be rejected; but 2.3 is rejected.

Based on the results of trend analysis, specific hypotheses 3.3, 3.6, and 3.9 are rejected. However, hypotheses 3.1, 3.2, 3.4, 3.5, 3.7, 3.8, 3.10(as stated in p. 76) must be accepted with caution. The weight of the overall results on the AB interaction effect tend to indicate that the group profiles were similar in form. A difference in group profiles would indicate that the effects of enrichment duration and timing were significant, which means that the effects of enrichment, if introduced at different ages, were not equal, and would agree with the critical period hypothesis. The results of this experiment, therefore, give little support to the hypothesis of critical periods during post-weaning development of the albino rat.

g. Reliability Estimates of PEP variables.

Tables LI and LII present the test-retest reliability coefficients for PEP latencies and amplitudes ~~of four events~~ at four occassions. They indicate that the PEP obtained from awake, restrained albino rats are highly reliable.

Tables LIII and LIV present the relationship for PEP latencies and amplitudes obtained from two different locations on the rat's skull. They indicate that PEP recorded from these locations were highly similar.

h. PEP Configuration.

Figure 12 presents the wave form of a typical PEP record.

In general, wave forms similar to those reported by Edwards[1] were observed. There were four major identifiable and reliable events at 47-62 msec., 65-125 msec., 100-253 msec., and 210-310 msec., from the onset of the stimulus.

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1 H.P. Edwards, W. 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. 136.

Table LI.-

Test-Retest Reliability Coefficients of Photic Evoked Potentials Latency Between Electrodes One and Two, and Between Electrodes Two and Three, Studied at Weaning and Three Subsequent Occasions.

Occasion	Reliability Coeffients[a]	
	Electrodes 1 & 2	Electrodes 2 & 3 [b]
Weaning	.87	,93
Eight Weeks	.91	.92
Twelve Weeks	.89	.89
Sixteen Weeks	.92	.91

a Reliability Coeffieients were determined by computing Pearson r Coefficients of Correlation between the photic evoked responses to the first fifty flashes and the second fifty flashes of light.

b For electrode labels, refer to Fig. 1

Table LII.-

Test-Retest Reliability Coefficients of Photic Evoked Potentials Amplitude Between Electrodes One and Two, and Between Electrodes Two and Three, Studied at Weaning and Three Subsequent Occasions.

Occasion	Reliability Coefficients[a]	
	Electrodes 1 & 2	Electrodes 2 & 3[b]
Weaning	.84	.81
Eight Weeks	.87	.85
Twelve Weeks	.85	.88
Sixteen Weeks	.86	.88

a Reliability Coefficients were determined by computing Pearson r Coefficients of Correlation between the photic evoked responses to the first fifty flashes and the second fifty flashes of light.

b For electrode labels, refer to fig. 1.

Table LIII.-

Coefficients of Correlation of Photic Evoked Potentials LATENCIES
Recorded From Two Locations on the Rat Skull at Weaning
and Three Subsequent Occasions.

Occasion	Coefficient of Correlation [a]
Weaning	.82
Eight Weeks	.83
Twelve Weeks	.78
Sixteen Weeks	.76

a Coefficients of Correlation were based on photic evoked responses to one hundred flashes of light.

Table LIV.-

Coefficients of Correlation of Photic Evoked Potentials Amplitudes Recorded From Two Locations on the Rat Skull at Weaning and Three Subsequent Occasions.

Occasion	Coefficient of Correlation[a]
Weaning	.78
Eight Weeks	.79
Twelve Weeks	.75
Sixteen Weeks	.74

a Coefficients of Correlation were based on evoked responses to one hundred flashes of light.

Note : Amplitude 1 = 1 - 0
Amplitude 2 = 1 - 2
Amplitude 3 = 3 - 2
Amplitude 4 = 3 - 4

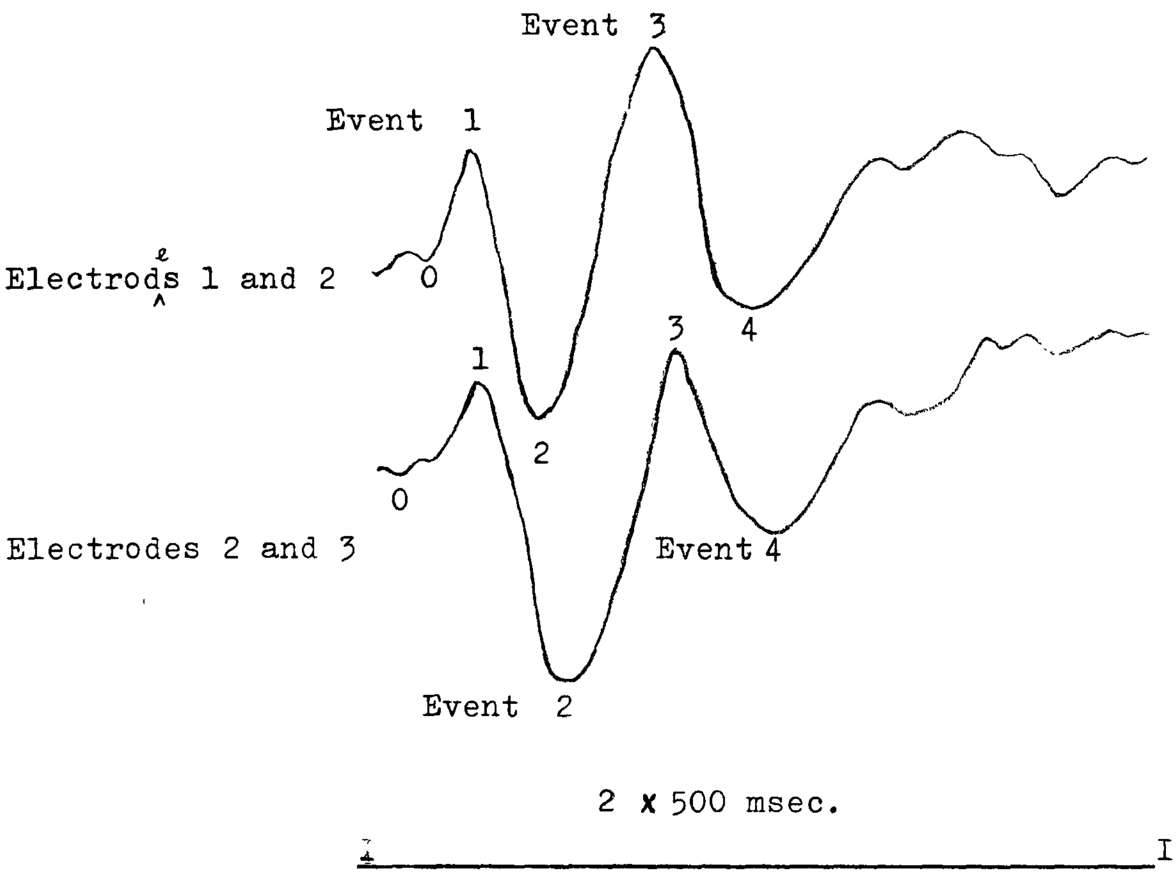

Figure 12.- A typical Evoked Potential Record Obtained From a Single Albino Rat at Two Different Electrode Placements.

2. Discussion of Results.

Before the results are discussed, the writer wishes to point out that there are several limitations in this experimental design. Firstly, like most studies on early differential rearing, this study is essentially factorial and not functional in design, as defined by Andrews[2]. It is an exploratory research , concerned primarily with the physiological and behavioral consequences of differential rearing, and not endeavoring to discover concomittant variations between the independent and dependent variables. The four levels of enrichment duration and timing were arbitrarily chosen, because the range of these variables have not been fully established in the literature. The optimal degree and quality of stimulation for enrichment at various specific age levels of the albino rat is still unknown. Secondly, the age variable imposes a unique and complex problem in this design. In addition to the timing of enrichment at a specific age level, other confounding variables associated with age, such as maturation, interference effects due to testing such as practice effects, proactive and retroactive inhibition, are also involved;

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2 T.G. Andrews, "An Introduction to Psychological Methodology", in Methods of Psychology, T.G. Andrews, Ed., New York, John Wiley, 1948, p. 9.

so that it is difficult to specify the nature of the differences among the four experimental groups. If significant differences were found, they could be attributed to different processes of maturation, to the effect of enrichment, to the duration of enrichment, and to the introduction of enrichment at a certain age. However, maturation, practice effects etc. are assumed to be equally distributed among the four groups, when they are compared with each other at a specific age level. Body weight, which may be used as an index of maturation, was found to be almost the same for all groups, and experimental conditions and testing situations were maintained equal for all subjects. Thirdly, since the sample chosen was small, observed differences must attain a good size in order to exclude any probability due to chance alone. The loss of one subject in group four at twelve weeks of age further enhances the problem, since the equivalence of the groups was statistically destroyed. In its absence, the mean score of group four was extrapolated as the score of the subject. Fourthly, there is no behavioral test for the albino rat, whose validity has been well established, that permits normative comparison of individual subjects of small groups to a large population of normal or control animals. Hence the results of this study must be interpreted with caution.

The tests of overall significance, using the two factor analysis of variance with repeated measures design, applied to the PEP variables showed a few significant F values for the Age factor, but no significant F values on the Enrichment factor and Enrichment-Age interaction. The significant results on the effects of Age agree with findings by Rose[3] who demonstrated that PEP variables, especially latencies, changed as a function of time. The Age factor, however, is not of principal concern in this study. The failure of the effects due to Enrichment and AB interaction to attain significant values is probably partly due to the smallness of the sample. One way analysis of variance, applied to the enrichment variable alone by comparing experimental groups cross-sectionally at each of the four age levels, gave similar insignificant results on the PEP data except that of variability of wave form. However, Scheffe's test, applied to the enrichment factor alone by comparing group totals summed across the four age levels, showed that the groups differed significantly on several PEP latencies, amplitudes, and variability.

It is interesting to note that the majority of latency

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3 G.H. Rose, "The Development of Visually Evoked Electrocortical Responses in the Rat", Developmental Psychobiology, Vol. 1, No.1, 1968, p. 35-40.

differences were in the expected direction, in view of the findings by Edwards _et al._[4] who concluded that enrichment has measurable effects on the later components of the _PEP_ in rats, with enriched rats having shorter latencies than impoverished rats. This direction of _PEP_ latency differences between enriched and impoverished rats is also supported by a number of other investigators. It has been concluded by Ertl[5] that latency of the evoked response is inversely correlated with neural efficiency. Krech, Rosenzweig and co-authors[6] have repeatedly found that complex environment produced measureable changes in the cholinesterase level of the brain which could be used as an index of synaptic facilitation. Hebb,[7] in apparent agreement with this position, has proposed a stimulus-deprivation theory that all organisms need a long period of 'perceptual learning' for the organization of the whole central nervous system.

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4 Edwards, Barry and Wyspianski, _Op. Cit._, p. 133-138.

5 F.R. Chalke and J.P. Ertl, "Evoked Potentials and Intelligence", _Life Sciences_, Vol. 4, 1965, p. 1319-1322.

6 D. Krech, M.R.Rosenzweig and E.L. Bennett, "Environmental Impoverishment, Social Isolation, and Changes in Brain Chemistry and Anatomy", _Physiology and Behaviour_, Vol. 1, 1966, p. 99-104.

7 D.O. Hebb, _The Organization of Behaviour_, New York, John Wiley, 1949, p. 296.

However, the direction of amplitude differences, after Scheffe's test was applied, was paradoxical, with some differences in the expected direction and others contrary to expectation. According to Melzack's[8] conceptual model, amplitudes for the group with the longest enrichment should be larger than those for less enriched groups. He proposes that since impoverished animals tend to be more easily aroused in a novel situation, resulting in inadequate filtering of sensory input on relevant memories of stimuli, which in turn leads to fluctuations of the magnitude of brain activities, their amplitudes are expected to be less than less aroused animals or enriched animals. Findings by Frommer and Livingston[9] supported this view. The authors found that under states of arousal, evoked responses decreased in amplitude and duration. The results of ~~this~~ the present study, however, showed that animals reared in a constant environment, whether it be enriched or impoverished, had larger amplitudes than animals reared in the impoverished condition at first

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8 R. Melzack, "Effects of Early Experience on Behaviour : Experimental and Conceptual Considerations", in Disorders of Perception, P.H. Hoch and J. Zubin, Ed., New York, Grune and Stratton, 1965, p. 271-299.

9 G.P. Frommer and R.B. Livingston, "Arousal Effects on Evoked Activity in a 'Nonsensory System'", Science, Vol. 139, 1963, p. 502-504.

and then transferred to the enriched condition. Thus, it appears that the reversal of environments, rather than enrichment itself, has affected such changes in PEP amplitudes.

The direction of variability differences, according to Scheffe's test results, agrees with Melzack's conceptual model described above.

Since the overall tests of significance on the main effect of enrichment were insignificant, the first hypothesis, stated at the end of the first chapter, is not rejected.

Previous findings on the effects of differential rearing on behavioral variables are not unanimous. The Hebbian theory [10] that impoverished animals are inferior problem-solvers than enriched animals has been supported by a large number of subsequent investigators : Hymovitch[11], Melzack and Burns[12], Thompson and Heron[13], Brown[14] and others.

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10 D.O. Hebb, "The Effects of Early Experience on Problem-Solving at Maturity", The American Psychologist, Vol. 2, 1947, 0. 306-307.

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

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

13 W.R. Thompson and W. Heron, "The Effects of Restricting Early Experience on the Problem-Soving Capacity of Dogs", Canadian Journal of Psychology, Vol.8, 1954,p. 17-31.

On the other hand, some investigators, Reid et.al.,[15] and Zimbardo and Montgomery[16] propose that the observed differences in problem-solving abilities between enriched and impoverished animals were due to greater activity in impoverished animals, therefore, the behavioral differences are explained in terms of a motivational theory in stead of an efficiency theory. In view of such conflicting theories, in the present study a number of behavioral tests were administered, including a brightness discrimination task and an avoidance conditioning task for testing the ability to solve problems; and activity, operant behavior and emotionality rating for measuring motivation and arousal. The use of a number of relatively independent behavioral tests also avoids oversimplistic methodological weaknesses as pointed out by Weiss and Heller[17].

The one way analysis of variance results were found

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14 R.T. Brown, "Early Experience and Problem-Solving Ability", Journal of Comparative and Physiological Psychology, Vol. 65, 1968, p. 433-440.

15 L.D. Reid, J.H. Gill and P.B. Porter, "Isolated Rearing and Hebb Williams Maze Performance", Psychological Reports, Vol. 22, No. 3, 1968, p. 1073-1077.

16P.J. Zimbardo and K.C. Montgomery, "Effects of 'Free-Environment' Rearing Upon Exploratory Behaviour", Psychological ~~Bulletin~~ Reports, Vol. 3, 1957, p. 589-594.

17 B. Weiss and A. Heller, "Methodological Problems in Evaluating the Role of Cholinergic Mechanisms in Behavior", Federation Proceedings, Vol. 28, No. 1, 1969, p. 135-146.

to be insignificant on all behavioral tests except Skinner's operant behaviour. However, differences among the groups, though insignificant, tend to indicate that groups with longer duration and early introduction of enrichment performed,on the whole, better on the problem-solving tasks, and were less active and emotional.

Trend analysis was used to test statistically the differences in group profiles of PEP and Emotionality measures, in terms of linear, quadratic and cubic trend components. The results of the majority of these tests were insignificant; however, specific hypotheses 3.3, 3.6 and 3.9 were rejected. On this basis, the third null hypothesis as stated in the first chapter is partially rejected.

The critical period hypothesis states that there are limited time epochs in the life of the rat beyond which certain stimuli will exert minimal or no influence on the rat's development. Thus, if critical periods exist, the group profiles should differ significantly, and AB interaction effects should be significant. The results of the present investigation, therefore, do not favour such hypothesis.

However, longitudinal graphical representations of the trends, which show the changes in PEP and emotionality as a function of time, provide some important clues regarding the effects of reversal and permit some comments to be made.

The figures contains some inconsistent trends. For example, some trends are quadratic while others on the same variable are cubic or linear. In the latency of events three and four, group three showed a decrease in latency at eight weeks old, while all other groups showed increases. Again, in the amplitude of event four, group two showed an increase in amplitude after the environment was reversed, while in most other cases, reversal of environment was followed by a decrease in amplitude agreeing with Melzack's conceptual model. In general, the results tend to indicate that environmental reversal from the impoverished to the enriched condition produces no clear directionality with regard to PEP latency and amplitude changes. The figures, however, provide the following clues : first, while the latency development was fairly even and predictable for groups reared in constant environments (fully enriched and fully impoverished), latencies varied greatly in groups two and three whose environments were reversed at some stage in their lives. Second, changes were found to occur in the majority of cases after reversal of environments, the critical period hypothesis is therefore not supported, at least not during the experimental period of four to twelve weeks of the rat's life. The PEP data showed abrupt irregular changes four weeks after the environmental reversal. The most probable explanation for these sharp changes is that the impoverished animals had very little opportunity for social contact ot perceptual oragnization before the environment was reversed. This sudden wealth of experiences brought on by the enriched condition may have some disturbing effects on their cerebral and psychological development. According to Hebb[18], the enriched condition provides opportunity for perceptual organization which may generalize to nonspecific situations because the whole cortex is involved. The above explanation is also made in the light of Melzack's[19] conceptual model that chronic enrichment may lead to memory storage and decreased arousal. Furthermore, Thompson and Heron[20] found that enriched animals were socially dominant, so that the effects of enrichment on the rats already in the enriched condition may not be the same as that on rats newly brought into the cage. Thus, from the results presented in the previous section, it appears that environmental reversal exerts some influence on the development of the rat, but the present study is not able to determine whether there is a set directionality in PEP and behavioral changes.

Findings discussed here are considered tentative and preliminary. They are discussed according to several conceptual models. The writer wishes to point out that small differences in physiological characteristics, such as

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18 see p. 159.

19 see p. 40.

20 see p. 21.

PEP, may be important in affecting behaviour, according to Rosenzweig and Bennett[21].

Several suggestions for future research emerge from this study. First, it remains the task of future reseach to devise valid behavioral measures of cognitive, perceptual, and emotional development in lower animals. The behavioral tests used in the present study have doubtful validity. Second, this study should be replicated with a bigger sample. Third, in testing the critical period hypothesis, it may be more logical and fruitful to study the effects of environmental reversal at an earlier age in the rat's development. Instead of ordinary laboratory cages, maternity cages for preweaning animals could be used. Fourth, in order to establish a functional relationship between enrichment and various dependent variables, shorter time intervals between successive reversal of environments should be used. Fifth, if a battery of physiological and behavioral tests are used, a multivariate statistical analysis, such as factor analysis or multiple discriminant analysis should be performed to identify the more relevant variables. Sixth, long term effects should be studied, by maintaining and testing the subjects at several time intervals after environmental reversal. Seventh, studies should also be conducted to

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21 See p. 39.

investigate the effects of a different type of environmental reversal : early enrichment followed by impoverishment.

For reasons given in the above section, the critical period hypothesis needs further investigation.

SUMMARY AND CONCLUSIONS

This investigation was designed to assess the effects of duration and timing of differential rearing on the photic evoked potentials and behavior of albino rats from weaning to the age of sixteen weeks. Its primary purpose is to test the critical period hypothesis which asserts that after limited time epochs enrichment will exert minimal or no effect on the maturing organism. Its second purpose is to check whether the experimental groups differed at various stages of development in differential environments on specific photic evoked potentials and behavioral characteristics.

Three main hypotheses were tested in this experiment. The first hypothesis states that when albino rats reared in an enriched environment at four, eight, and twelve weeks of age for periods of twelve, eight, and four weeks respectively, and rats receiving no enrichment throughout the experimental period of twelve weeks are compared, no significant differences develop in the photic evoked potentials taken at four week intervals. The second hypothesis states that when the four groups of rats defined above are compared, there are no significant differences in the performance of the groups on a brightness discrimination task, a shuttle box experiment, an operant task, and activity measure, and an emotionality rating. The third hypothesis states that when the longitudinal changes in photic evoked potentials and the direction of these changes are compared among the four groups of rats defined above, there are no significant differences among the groups in photic evoked potentials development.

For the first hypothesis, a two factor with repeated measures on one factor analysis of variance was used as statistical test of significance of overall effects contributed by the duration and timing of enrichment and their interaction. Scheffe's test was used as statistical test of significance for individual comparisons of group totals. Since the results of the overall tests on the enrichment factor were insignificant, the first hypothesis is not rejected. However, from Scheffe's test, there were some indications that small differences appeared on both photic evoked potentials and emotionality among the groups. The direction of the differences found was as expected in the case of latency, wave form variability, and emotionality taken as a whole, but was paradoxical in the case of amplitudes.

For the second hypothesis, a one way analysis of variance was applied to the behavioral data, except that of emotionality, in which case the two factor analysis of variance was used, as statistical tests of significance. Results were insignificant except in the case of operant conditioning. On this basis, the second hypothesis is partially rejected. Although differences were small, the direction of the majority of differences was as expected. In general, longer and earlier enriched animals performed better on brightness discrimination and avoidance behavior, were less active and emotional, and made more lever presses for food.

For the third hypothesis, trend analysis was used as statistical analysis of Photic evoked potentials and emotionality group profiles as a function of age. The results were predominantly insignificant; but three specific variables showed significant differences in trend components among the groups. On this basis, the third hypothesis is partially rejected. There appears little support for a critical period hypothesis. Figural representations of changes in photic evoked potentials during development showed that upon reversal of environment, from impoverished to enriched, the majority of latencies and amplitudes decreased; the direction of the former was as expected , but that of the latter was contrary to expectation.

The results were explained in terms of several conceptual models in the current literature. Several limitations of this investigation were pointed out, and implications for further research were made.

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Ader, R. and A. Schaefer, "Effects of Early Experiences on One-Trial Avoidance Conditioning", Psychonomic Science, Vol. 10, No. 7, 1968, p. 235-236.

The authors propose that the observed differences between handled and trained rats are the results of previous learning and support their hypothesis that in avoidance behavior, early nonspecific experience is to be distinguished from previous experience.

Becker, G. and T.B. Flaherty, "Effects of Post-weaning Tactile Stimulation on Emotionality and Social Dominance in the Rat", Psychological Reports, Vol. 19, 1966, p. 363-366.

This study verifies earlier findings that handled rats are less timid, defined in terms of cage-emergence latency; less fearful, defined in terms of eating behavior; and socially dominant, defined in terms of food competition; than controls.

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The authors find that of all the cortical areas examined, largest differences when comparing enriched and isolated rats appear in the occipital cortex.

Bennett, E.L., M.C. Diamond, D. Krech and M.R. Rosenzweig, "Chemical and Anatomical Plasticity of Brain", Science, Vol. 146, 1964, p. 610-619.

This is one of a series of studies by the authors on the effects of environment on brain structure and chemistry, which concludes that the cortical choinesterase level, cortical/subcortical weight ratio, and brain weight as a whole, are affected by early experience, and that this effect is highly repeatable. In addition, enrichment is more effective in inducing cerebral changes than impoverishment.

Bennett, E.L., M.R. Rosenzweig and M.C. Diamond, "Rat Brain : Effects of Environmental Enrichment on Wet and Dry Weights", Science, Vol. 163, 1968, p. 825-826.

In this brief report, the authors conclude that, since results on the effects of environment on the dry weight of the brain are identical with that on the wet brain, the heavier brain of enriched littermates is not due to 'water'.

Bennett E.L. and M.R. Rosenzweig, "Potentials of an Intellectually Enriched Environment", Paper given at Symposium 'Dysnutition in the Seven Ages of Man' at the University of California Medical School, San Fransisco, on Jan. 12, 1969, 25 p.

This paper reviews recent studies on the effects of environmental complexity by the California group of investigators. It produces evidence of the importance of environmental nourishment to the developing human.

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The authors reply to Karczmar's objections concerning the accuracy of acetylcholinesterase measurement in the California experiments. While admitting to some inaccuracy, they argue that their results are genuine because numerous replication studies produce results in the same direction and of the same order of magnitude. In addition, they point out that small differences in brain enzymes are significant in affecting behavior.

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The authors investigate the behavior of enriched and deprived rats , and find that the enriched littermates are superior in maze-solving ability, but do not differ from the deprived in brightness discrimination or emotionality.

Brown, R.T., "Early Experience and Problem-Solving Ability", The Journal of Comparative and Physiological Psychology, Vol. 65, 1968, p. 433-440.

This recent study is based on earlier work by Hymovitch and Forgus. The author rears rats under four environmental conditions, and concludes, on the basis of several tests of animal behavior, that the superiority of enriched littermates is due to greater use of extra-field cues.

Chalke, F.R. and J.P. Ertl, "Evoked Potentials and Intelligence", Life Sciences, Vol. 4, 1965, p. 1319-1322.
The authors find that there are significant differences in the latencies of the averaged visual evoked responses among groups of human subjects classified as high, average or low intelligence. This study lends support to Ertl's hypothesis that latency of the evoked response is related to neural efficiency.

Denenberg, V.H. and G.G. Karas, "Interactive Effects of Age and Duration on Infantile Experience on Adult Learning", Psychological Reports, Vol. 7, 1960, p. 313-322.
The relevant findings of this paper are that, when various age froups, various types of stimulation and the degree of its duration are studied in the rat, restricted animals show measurable improvement upon reversal of the environment, thus disagreeing with the critical period hypothesis.

Denenberg, V.H., "Critical Periods, Stimulus Input, and Emotional Reactivity : A Theory of Infantile Stimulation", Psychological Review, Vol. 71, No. 5, 1964, p. 335-351.
Upon reviewing studies on the critical period hypothesis, the author proposes a monotonicity theory of infantile stimulation, that the relationship between the amount of stimulus input and later performance on various tasks of moderate difficulty is U-shaped. In addition, the author suggests that there are different critical periods for different types, qualities, and intensities of stimulation; and for different kinds of behavior measured, but in each case, there is an optimal level of stimulation.

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Essman, W.B., "Differences in Locomotor Activity and Brain-Serotonin Metabolism in Differentially Housed Mice", Journal of Comparative and Physiological Psychology, Vol. 66, No. 1, 1968, p. 244-246.

In this study, mice are reared in isolation or aggregation from weaning until forty-five days of age. The author finds that isolated animals are more active, have higher brain-serotonin levels, and increased rate of brain-serotonin turn-over.

Forgays, D.G., and J.W. Forgays, "The Nature of the Effect of Free-Environmental Experience in the Rat", The Journal of Comparative and Physiological Psychology, Vol. 45, 1952, p. 322-328.

In this early study, rats are reared in small cages but without perceptual restriction and in large cages with perceptual restriction. The authors find that the former group of rats are superior in problem-solving, and concludes that perceptual restriction exerts greater effects on the organism than spatial restriction, and lends support to Hebb's theory of stimulus deprivation.

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Based on Hebb's original study, the author studies rats reared in environments differing in complexity in terms of opportunity for visual and/or proprioceptive experience, The author concludes that early experience determines the emotional and cognitive ability of the rat, and further suggests that the quality of early experience affects the testing of mental hypotheses during problem-solving at adulthood.

Frommer, G.P. and R.B. Livingston, "Arousal Effects of Evoked Activity in a 'Nonsensory' System", Science, Vol. 139, no. 3554, 1963, p. 502-504.

The relevant part of this article states that on reduction of arousal defined by the use of behavioral and EEG criteria, evoked responses show an increase in both amplitude and latency.

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This study is relevant only in its finding that evoked potentials reflect subjective variables such as attention and alertness.

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

In this early study, the author compares rats reared in laboratory cages with rats reared as pets on the Hebb-Williams maze test of animal intelligence. He finds that pet animals are superior problem-solvers.

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The relevant section of this publication contains Hebb's stimulus deprivation theory. He proposes that differential early perceptual experience is an important determinant of an individual's Problem-solving capacity. In addition, he supports the critical period hypothesis by stating that early perceptual learning tends to be permanent and nonspecific, involving the whole cortex.

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 early study shows that enrichment is beneficial to the animal: Enriched rats are superior problem-solvers and less emotional. The author interpretes this finding after Hebb in terms of the transferrence of perceptual learning to problem-solving situations. He further suggests that enriched rats makes more use of extrafield cues during testing. In addition, he finds that the period between thirty and seventy-five days of age is most sensitive in developing behavior patterns.

Karczmar, A.G., "Is the Central Cholinergic Nervous System Overexploited ?", Federation Proceedings, Vol. 28, No. 1, 1969, p. 147-157.

In this recent article, the author outlines the methodological problems of measuring synaptic transmitter chemicals and relating them to behavior. He criticizes the California investigations for inaccuracy in measuring acetylcholinesterase activity and straining for significance in small differences.

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This article is relevant from the methodological point of view. It discusses the characteristics of the evoked response in the mature rat, and the optimal placements of needle electrodes.

Melzack, R., "Effects of Early Experience on Behaviour : Experimental and Conceptual Considerations", in Disorders of Perception, P.H. Hoch and J. Zubin, Ed., New York, Grune and Stratton, 1965, p. 271-299.

This important publication summarizes the experimental findings by Melzack and his associates on the effects of environmental restriction. Some behavioral characteristics of isolated dogs are : easily excited, socially submissive, difficult to attend selectively, and poor problem-solvers. Some physiological characteristics are : high frequency EEG in novel situations, fluctuating evoked responses with reduced amplitude and increased wave form variability. These findings are explained by means of a neurological model which hypothesizes that as a result of restriction, stimuli in a novel situation have no prior associations to allow adequate selective filtering of relevant stimuli, and in consequence, the entire sensory input bombards the brain producing excessive arousal, which in turn disrupts perceptual discrimination and adaptive response.

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Reid, L.D., J.H. Gill and P.B. Porter, "Isolated Rearing and Hebb Williams Maze Performance", Psychological Reports, Vol. 22, No. 3, 1968, p. 1073-1077.

This paper disagrees with the literature on the superiority of enriched animals in problem-solving. The authors conclude that early rearing affects motivational factors, and that maze-solving efficiency of enriched and isolated littermates is equalized by reducing the effect of emotionality.

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This article compares bright and dull children on photic evoked potentials. The authors conclude that amplitude rather than latency differentials are significant, which is inconsistent with Ertl's findings.

Rose, G.H., "The Development of Visually Evoked Electrocortical Responses in the Rat", Developmental Psychobiology, Vol. 1, No. 1, 1968, p. 35-40.

In this study, the development of photic evoked potentials in albino rats from birth to thirty-five days of age. The author observes a definite sequence of wave form changes and relates that to onset of optic myelinization.

Rosenzweig, M.R., E.L. Bennett and M.C. Diamond, "Transitory Components of Cerebral Changes Induced by Experience", Proceedings, 75 th. Annual Convention, A.P.A., Vol. 2, 1967, p. 105-106.
This is a typical study of the California group of investigators. The authors find that cholinesterase changes are related to synaptic modifications rather than memory encodings. The fluctuating cerebral changes during training in enriched rats are explained as temporary memory storage activities. In addition, the authors find that cerebral activities are maximal with thirty days of enrichment and then declines, which appears to support Denenberg's hypothesis.

Rosenzweig, M.R. and A.L. Leiman, "Brain Functions", Annual Review of Psychology, Vol. 19, 1968, p. 55-98.
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Scott, J.P., "Critical Periods in Behavioral Development", Science, Vol. 138, 1962, p. 949-958.
This publication reviews the experimental findings both supporting and refuting the critical period hypothesis. The author suggests that critical periods may be complex, with one type of critical periods based on the development of physiological mechanisms, and another on psychological processes.

Thompson, W.R., R. Melzack and T.H. Scott, '"Whirling Behavior' in Dogs as Related to Early Experience", Science, Vol. 123, 1956, p. 939.
In this brief report, the authors find that restricted dogs are easily aroused, emotional, and unable to control their behavior. This finding replicates earlier studies relating environment to emotional reactivity.

Weiss, B. and A. Heller, "Methodological Problems in Evaluating the Role of Cholinergic Mechanisms in Behaviour", Federation Proceedings, Vol. 28, No. 1, 1969, p. 135-146.

The authors of this paper criticize the California experiments for their oversimplistic speculations on the relationship between cholinergic system and behavior. They assert that it is a methodological error to postulate biochemical mechanisms from the results on a simple behavioral task, which may not even be valid.

Woods, P.J., "The Effects of Free and Restricted Environmental Experience on Problem-Solving Behavior in the Rat", Journal of Comparative and Physiological Psychology, Vol. 52, 1959, p. 399-402.

The author studies the problem-solving behavior of rats reared in a restricted environment to the age of sixty days, and finds that the environmental effect is not quite permanent, since on reversal of environment, the subsequently enriched rats show some improvement. This finding appears to refute the critical period hypothesis.

Zimbardo, P.J. and K.C. Montgomery, "Effects of 'Free-Environment' Rearing upon Exploratory Behavior", Psychological Reports, Vol. 3, 1957, p. 589-594.

In this study, restricted animals and enriched animals are compared on the Hebb-Williams maze performance. The authors find that restricted animals are inferior in the performance on Hebb-Williams maze, but also tend to explore more, which increases their error score. They propose a motivational hypothesis of the effect of early environments, and disagree with Hebb that the superiority of enriched animals in problem-solving is attributable to the acquisition of complex cerebral organizations.

APPENDIX 1

PHOTIC EVOKED POTENTIAL LATENCIES

APPENDIX 1

PHOTIC EVOKED POTENTIAL LATENCIES[1]

a. First Event

Subject[2]	Four Weeks[3]	Eight Weeks	Twelve Weeks	Sixteen Weeks
Group One				
4	47	50	56	54
6	60	54	60	56
11	53	48	48	54
13	48	50	50	58
Group Two				
1	58	50	51	58
8	63	53	50	65
9	52	49	54	52
14	56	50	58	58
Group Three				
2	65	48	52	55
7	65	53	58	60
12	53	49	50	60
16	59	50	57	60
Group Four				
3	60	55	56	62
5	75	55	58	55
10	50	62	--	--
15	59	50	55	52

1 Latencies are recorded in milliseconds.

2 During the experiment, each subject was coded with an identifying number. Each litter of four animals was represented by four numbers in serial. For example, subjects 1,2,3, and 4 were littermates of the first litter; subjects 5,6,7, and 8 were littermates of the second litter; and so on.

3 The number of weeks signifies the age of the subjects when photic evoked potentials were recorded.

APPENDIX 1

PHOTIC EVOKED POTENTIAL LATENCIES

b. Second Event

Subject	Four Weeks	Eight Weeks	Twelve Weeks	Sixteen Weeks
Group One				
4	74	110	83	74
6	100	68	76	75
11	72	65	68	93
13	70	68	65	78
Group Two				
1	86	70	74	75
8	85	118	70	90
9	115	110	68	94
14	105	125	72	116
Group Three				
2	90	63	70	114
7	114	70	76	85
12	70	66	72	86
16	75	116	112	105
Group Four				
3	83	72	75	81
5	96	84	77	85
10	70	95	--	--
15	82	67	125	110

Note.- All photic evoked potential latencies shown in APPENDIX 1 were based on averaged evoked responses to 200 flashes of light : 100 each from electrodes 1 & 2 and electrodes 2 & 3. For electrode labels, refer to Fig. 1.

APPENDIX 1

PHOTIC EVOKED POTENTIAL LATENCIES

c. Third Event

Subject	Four Weeks	Eight Weeks	Twelve Weeks	Sixteen Weeks
Group One				
4	100	185	180	186
6	208	225	180	160
11	165	142	172	185
13	124	123	140	160
Group Two				
1	160	182	177	180
8	185	215	160	195
9	195	216	165	186
14	173	176	158	185
Group Three				
2	200	160	185	190
7	190	190	188	183
12	195	160	175	190
16	210	185	180	176
Group Four				
3	160	200	173	186
5	165	245	190	200
10	205	253	---	---
15	167	180	180	162

APPENDIX 1

PHOTIC EVOKED POTENTIAL LATENCIES

d. Fourth Event

Subject	Four Weeks	Eight Weeks	Twelve Weeks	Sixteen Weeks
Group One				
4	210	255	260	265
6	276	268	310	254
11	270	270	252	260
13	220	254	226	250
Group Two				
1	250	275	270	270
8	278	325	280	295
9	309	266	228	283
14	203	266	255	310
Group Three				
2	298	220	300	244
7	303	268	286	279
12	250	270	260	280
16	260	267	280	248
Group Four				
3	293	345	266	300
5	275	325	294	270
10	295	328	---	---
15	254	260	295	228

APPENDIX 2

PHOTIC EVOKED POTENTIAL AMPLITUDES

APPENDIX 2

PHOTIC EVOKED POTENTIAL AMPLITUDES[1]

a. First Event (A-B)

Subject[2]	Four Weeks[3]	Eight Weeks	Twelve Weeks	Sixteen Weeks
Group One				
4	5.3	9.2	4.8	10.2
6	9.4	4.2	8.6	6.4
11	10.2	8.0	15.1	7.0
13	4.8	8.0	9.3	9.2
Group Two				
1	5.2	9.0	6.0	17.2
8	9.6	6.2	5.6	4.0
9	4.0	12.0	6.8	21.2
14	3.2	8.4	8.2	7.0
Group Three				
2	5.8	7.6	15.2	5.2
7	8.6	12.3	5.2	8.4
12	6.4	19.0	7.6	8.6
16	3.2	11.4	11.2	9.2
Group Four				
3	5.2	12.0	11.0	18.8
5	3.0	4.5	5.1	6.0
10	10.4	7.8	---	---
15	3.8	4.0	8.4	13.4

1 Amplitudes are recorded in microvolts, (μV).

2 Throughout the experiment, each subject was given an identifying number. Each litter of four animals was represented by four numbers in serial. For example, subjects 1,2,3, and 4 were littermates of the first litter; subjects 5,6,7 and 8 were littermates of the second litter; and so on.

3 The number of weeks signifies the age of the subjects when photic evoked potentials were recorded.

APPENDIX 2

PHOTIC EVOKED POTENTIAL AMPLITUDES

b. Second Event (B-C)

Subject	Four Weeks	Eight Weeks	Twelve Weeks	Sixteen Weeks
Group One				
4	8.6	13.7	8.0	13.8
6	15.6	11.2	10.8	10.6
11	18.8	10.2	18.2	7.8
13	7.0	13.4	14.0	10.4
Group Two				
1	12.6	16.2	15.8	21.6
8	15.2	15.9	16.4	7.4
9	7.2	14.2	7.8	14.2
14	17.2	11.2	11.7	8.6
Group Three				
2	6.0	20.9	17.8	10.1
7	12.8	14.0	8.0	12.6
12	12.0	29.2	17.2	7.8
16	5.2	15.2	16.5	8.6
Group Four				
3	4.8	8.8	13.4	15.2
5	6.6	15.6	6.3	10.8
10	17.2	10.6	---	---
15	9.6	12.8	16.3	15.2

Note.- All photic evoked potential amplitudes shown in APPENDIX 2 were based on averaged evoked responses to 200 flashes of light : 100 each from electrodes 1 & 2 and electrodes 2 & 3. For electrode labels, refer to Fig. 1.

APPENDIX 2

PHOTIC EVOKED POTENTIAL AMPLITUDES

c. Third Event (C-D)

Subject	Four Weeks	Eight Weeks	Twelve Weeks	Sixteen Weeks
Group One				
4	8.3	6.2	12.8	15.6
6	9.6	11.0	23.6	17.0
11	12.0	18.4	25.1	9.6
13	11.0	11.0	12.4	16.6
Group Two				
1	11.8	14.0	11.6	24.1
8	12.8	14.4	10.6	12.6
9	12.4	15.9	24.4	15.4
14	21.2	12.0	8.0	13.6
Group Three				
2	12.4	13.2	18.2	16.1
7	8.0	10.0	11.2	15.8
12	13.2	18.6	7.6	13.8
16	4.0	7.4	21.0	9.6
Group Four				
3	7.5	13.0	16.4	14.4
5	10.1	17.6	24.1	13.2
10	16.8	14.0	---	---
15	18.4	24.8	15.6	11.0

APPENDIX 2

PHOTIC EVOKED POTENTIAL AMPLITUDES

d. Fourth Event (D-E)

Subject	Four Weeks	Eight Weeks	Twelve Weeks	Sixteen Weeks
Group One				
4	9.4	11.0	15.2	18.2
6	10.8	16.5	25.2	15.2
11	13.0	16.4	26.0	16.6
13	16.6	12.2	12.0	18.2
Group Two				
1	5.4	12.8	13.0	22.7
8	7.6	3.6	18.2	12.4
9	9.6	13.8	23.3	15.4
14	12.4	14.5	15.8	16.8
Group Three				
2	9.2	12.0	14.2	18.7
7	6.4	8.6	12.0	17.6
12	11.2	17.2	12.8	20.8
16	5.2	10.0	29.0	11.0
Group Four				
3	11.1	14.2	17.5	14.0
5	13.4	5.9	28.2	15.4
10	11.6	17.2	---	---
15	15.2	28.0	15.2	14.0

APPENDIX 3

BRIGHTNESS DISCRIMINATION SCORES

APPENDIX 3

BRIGHTNESS DISCRIMINATION SCORES[1]

Subject[2]	Score[3]
Group One	
4	39
6	42
11	45
13	20
Group Two	
1	50
8	40
9	44
14	50
Group Three	
2	48
7	50
12	49
16	50
Group Four	
3	48
5	36
10	45
15	46

1 The scores were obtained from a black-white brightness discrimination apparatus when the subjects were eightweeks old.

2 Throughout the experiment, each subject was given an identifying number. At the time of the testing, the subjects in Group One were enriched, while those in groups two, three, and four were impoverished.

3 Each score represents the total number of trials required by a subject to reach a criterion performance of eight consecutive correct responses out of ten trials. The maximum limit was set at fifty trials.

APPENDIX 4

AVOIDANCE LEARNING SCORES

APPENDIX 4

AVOIDANCE LEARNING SCORES[1]

Subject[2]	Score[3]
Group One	
4	85
6	93
11	150
13	94
Group Two	
1	150
8	122
9	68
14	55
Group Three	
2	53
7	150
12	138
16	148
Group Four	
3	75
5	130
10	--
15	129

1 The scores were obtained on an avoidance conditioning apparatus : the Shuttle Box, when the subjects were twelve weeks old.

2 Throughout the experiment, each subject was given an identifying number. At the time of the testing, the subjects in groups one and two were enriched, while those in groups three and four were retained in the impoverished environment.

3 Each score represents the total number of trials required by a subject to reach a criterion performance of nine consecutive correct avoidance responses out of ten trials. A maximum limit of 150 trials was set.

APPENDIX 5

ACTIVITY SCORES

APPENDIX 5

ACTIVITY SCORES[1]

Subject[2]	Score[3]
Group One	
4	0.5
6	1.2
11	3.0
13	0.3
Group Two	
1	0.5
8	7.0
9	0.3
14	4.0
Group Three	
2	5.8
7	2.5
12	1.0
16	3.0
Group Four	
3	2.8
5	4.5
10	---
15	1.5

1 The scores were obtained on a rodent activity platform when the subjects were sixteen weeks old.

2 Throughout the experiment, each subject was given an identifying number. Each group contained a subject from each of the four litters. At the time of the testing, the subjects in groups one, two, and three were enriched for periods of twelve, eight, and four weeks respectively, while those in group four were impoverished.

3 Each score represents the total number of body movements made by the subject in one hour, divided by 100.

APPENDIX 6

OPERANT CONDITIONING SCORES

APPENDIX 6

OPERANT CONDITIONING SCORES[1]

Subject[2]	Score
Group One	
4	5
6	16
11	12
13	8
Group Two	
1	4
8	45
9	35
14	50
Group Three	
2	65
7	35
12	35
16	20
Group Four	
3	7
5	3
10	--
15	5

1 The scores were obtained on a version of the Skinner Box when the subjects were sixteen weeks old.

2 Each group was composed of four subjects, one from each litter. At the time of the testing, the subjects in groups one, two, and three were enriched for periods of twelve, eight, and four weeks respectively; while the subjects in group four were impoverished.

3 Each score represents the total number of lever depressions made by a subject in one hour.

APPENDIX 7

EMOTIONALITY SCORES

APPENDIX 7

EMOTIONALITY SCORES[1]

Subject[2]	Four Weeks[3]	Eight Weeks	Twelve Weeks	Sixteen Weeks
Group One				
4	3	3	4	4
6	3	1	2	2
11	4	4	5	4
13	5	4	3	3
Group Two				
1	3	2	3	4
8	2	2	3	3
9	5	6	5	5
14	6	8	7	7
Group Three				
2	3	1	1	4
7	6	9	8	7
12	2	4	6	5
16	5	7	7	6
Group Four				
3	3	4	5	5
5	4	5	5	6
10	4	3	-	-
15	6	6	7	6

1 The scores were obtained from an Emotionality Rating Scale (see Appendix 8).

2 During the experiment, each subject was coded with an identifying number. Each group was represented by a subject from each of the four litters.

3 The number of weeks signifies the age of the subjects when the rating was performed.

APPENDIX 8

EMOTIONALITY RATING SCALE FOR THE ALBINO RAT

APPENDIX 8

EMOTIONALITY RATING SCALE FOR THE ALB INO RAT

Subject's Code : (Blind rating)   Date : ____________
Experimenter : ____________   Duration : (1 hr.)

Directions : Place a check in the space provided. Use only one check for each item. Rate each item separately. Not all items carry equal weights. In each testing session, rate subjects in a random order. Maintain the same conditions in the testing situation, as closely as possible, for all subjects. Avoid excessive handling. Inadequate description of any item should be noted.

1. Amount of defecation. (Count the no. of fecal pellets.)

   (0 - 2) (3 - 4) (5 - 6) (7 - 8) (9 - 10)

2. Amount of urination.

   (No urine) (slight) (large) (excessive)

3. Amount of squealing.

   (No sqealing) (few, just audible) (Many, loud)

4. Amount of exploration. (Measure the size of area explored)

   (large area travelled) (small area) (hiding-stationary)

5. Degree of fearfulness-apprehension.

   (slight) (passive avoidance) (jumping, escaping) trembling

6. Degree of aggressiveness.

   (slight) (signs of fretfulness) (threatening behaviour) (biting-chewing)

7. Degree of arousal-attention.

   (casual) (alert) (tense freezing posture) (highly ready to react)

APPENDIX 8

EMOTIONALITY RATING SCALE
FOR THE ALBINO RAT

Subject's Code : ______________

Date of Testing : ______________ Duration of Testing :
(1 hr.)

Directions : Add all the scores on the seven rating items according to the following weighting procedure. Place a check in the space provided.

1. Defecation : 0,1,2,3,4. Score __________
2. Urination : 0,1,2,3. __________
3. Squealing : 0,2,4. __________
4. Exploration : 0,2,4. __________
5. Fearfulness : 0,2,4. __________
6. Aggressiveness : 0,1,2,3. __________
7. Arousal : 0,1,2,3. __________

Total Score : __________

Overall Emotionality Rating :-

1	2	3	4	5	6	7	8	9
unemotional			emotional			very emotional		
(0-4)	(5-8)	(9-11)	(12-14)	(15-16)	(17-18)	(19-20)	(21-25)	

APPENDIX 9

VARIABILITY OF AVERAGED EVOKED POTENTIAL CONFIGURATION

APPENDIX 9

VARIABILITY OF AVERAGED EVOKED POTENTIAL CONFIGURATION[1]

Subject[2]	Four Weeks[3]	Eight Weeks	Twelve Weeks	Sixteen Weeks
Group One				
4	5	2	1	4
6	3	4	2	3
11	3	1	2	4
13	4	4	3	4
Group Two				
1	4	4	2	3
8	4	2	4	3
9	4	5	3	4
14	5	4	2	4
Group Three				
2	4	4	2	2
7	5	5	3	2
12	6	4	6	4
16	5	3	4	5
Group Four				
3	6	3	2	3
5	5	3	2	4
10	6	2	-	-
15	5	3	3	6

1 Variability scores were obtained from a rating scale shown in Appendix 10.

2 During the experiment, each subject was coded with an identifying number, hence the rating was blind.

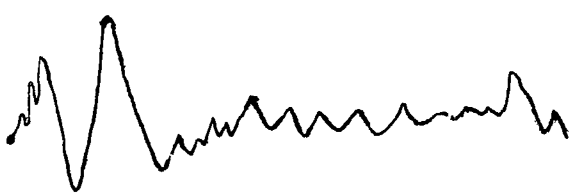
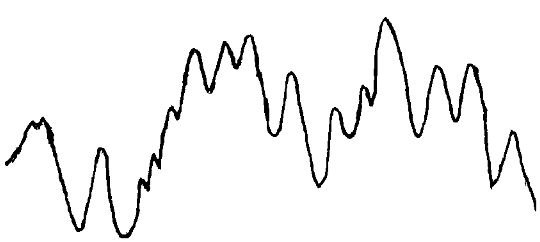
3 The number of weeks denotes the age of the subjects when the rating was performed.

APPENDIX 10

A RATING SCALE ON THE VARIABILITY OF AVERAGED EVOKED RESPONSES

APPENDIX 10

A RATING SCALE ON THE VARIABILITY OF AVERAGED EVOKED RESPONSES

CONFIGURATION	SCORE
	1
	2
	3
	4
	5
	6

APPENDIX 11

ABSTRACT OF

Effects of Duration and Timing of Early Differential Rearing on Photic Evoked Potentials and Behaviour of the Albino Rat.[1]

The present investigation is a longitudinal study having as its primary purpose the testing of the critical period hypothesis on a sample of Sprague-Dawley albino rats from weaning to the age of four months. It was designed to assess whether environmental reversal from the impoverished to the enriched condition has measurable effects on the photic evoked potentials and specific behavioral variables at four monthly intervals.

The experiment consisted of separating sixteen rats into four groups. One group was reared in the enriched condition throughout the experimental period; the second group was reared in small cages for four weeks and then transferred to the enriched condition for a period of eight weeks; The third group was impoverished for eight weeks and subsequently enriched for four weeks; the fourth group received no enrichment throughout the experiment. During the experiment, photic evoked potentials and behavioral test scores were obtained at monthly intervals. The behavioral tasks used were : brightness discrimination at eight weeks,

1 J.Y.C. Chien, master's thesis presented to the Faculty of Psychology of the University of Ottawa, Ontario, 1970, xii-201 p.

avoidance conditioning at twelve weeks, operant conditioning and activity at sixteen weeks, and emotionality rating at all four age levels.

The first hypothesis tested states that the four groups defined above do not differ in latency, amplitude, and variability of evoked potentials. No significant differences were found, hence this hypothesis is not rejected.

The second hypothesis tested states that the four groups do not differ in behavioral performance. No significant differences were found except in operant behavior. On this basis, the writer rejects this hypothesis in part.

The third hypothesis tested states that the four groups do not differ in their trend components showing changes of evoked potentials and emotionality as a function of time. No significant differences were found, except in latency of Event Three, amplitude of Event Two, and wave form variability. On this basis, this hypothesis is partially rejected. This finding does not support the critical period hypothesis. In general, changes in latency after reversal of environments are in the expected direction, but that of amplitude is paradoxical.

The results are discussed in terms of several conceptual models in the literature. However, due to certain limitations in the design, the results are interpreted with caution.