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ABSTRACT

Reports on research conducted to asses the utility of physiological responses for both the prediction of individual differences in attentional capacity and the monitoring of developmental changes in attentional responsivity. Specifically the experiments assessed: (1) Heart rate variability and newborn heart rate responses to illumination changes, (2) Heart rate responses of newborns to a simple auditory stimulus, (3) Heart rate responses of newborns as a function of age and experience, and (4) Heart rate conditioning in newborns. Also discussed are methodological problems in infancy research such as cohort effects and apparent secular trends and ontogenetic comparisons. Developmental designs for infancy research are considered. Other research areas are briefly discussed. (MS)

Final Report

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Title of Project:
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Abstract

An individual's ability to selectively attend to appropriate stimuli is a major determinant of successful survival. Historically, a major concern of education has been to improve the probability of survival and quality of life by training individuals to selectively respond to the environment. The research conducted during the tenure of grant NE-G-00-3-0013 was an attempt to assess the utility of physiological responses for both the prediction of individual differences in attentional capacity and the monitoring of developmental changes in attentional responsivity.

The initial proposal described the rationale and methods of an integrated research program investigating the relationship between heart rate responses and specific aspects of attentional responsivity during infancy and early childhood. During the granting period the research shifted to include children who were categorized as exhibiting an attentional deficit. The experiments conducted emphasize two basic approaches: First, physiological monitoring of psychologic processes (the recording of heart rate and respiratory responses during tasks associated with the psychological processes of sustained attention, orientation habituation, and conditioning would generate a noninvasive indicator, independent of verbal behavior, of the psychological processes); second, the identification of individual differences in spontaneous physiological activity as a predictive index of sustained attention. Moreover, during the period of the grant I became involved in the methodological problems associated with developmental research and the unique problems associated with infancy research. The final report includes descriptions of this work and copies of the publications associated with my attempt to delineate methods to solve the major problem.

The first approach resulted in a two-component model of attention. A unique property of the model is the decomposition of the construct of attention One common problem associated with the great number of psychophysiological inves tigations of attention has been the ambiguities associated with defining the co struct of attention. In a series of psychophysiological studies described in this report, different heart rate response components have been associated with different types of attention. Based upon empirical observations from these studies a two-component model of attention was presented that roughly parallels the two categories of attention identified by William James. The first component is associated with reactive attention or in James' terms passive and reflexive. This component is physiologically indexed by short latency directional heart rate responses to changes in stimulation. The second component is associated with sustained attention or in James' terms voluntary atte tion. The second component is paralleled in the nervous system by a generalize inhibition of motor and autonomic activity. This model has been tested with normal neonates and children some of whom have exhibited a deficit in their ability to sustain attention. The second approach, the identification of individual differences in spontaneous physiological activity as a predictive index of sustained attention, resulted in the development of a model relating central nervous system dysfunction to behavior and physiological activity.

The model speculates that individual differences in the ability to sustain attention is a behavioral manifestation of an imbalance in central inhibitory and excitatory systems. The central nervous system (brain) has inhibitory and excitatory systems which according to the continuity assumption should be

manifested in both the autonomic nervous system and in observable motoric behav The heart rate responses associated with sustained attention and described in the two-component model of attention are generally thought to be influenced by the inhibitory branch of the autonomic nervous system. Individual differences in the tonic level of this inhibitory branch have been demonstrated in this report to predispose subjects to exhibit patterns of physiological activity and behavior associated with sustained attention.

I. Rationale for conducted research

An individual's ability to selectively attend to appropriate stimuli is a major determinant of successful survival. Historically, a major concern of education has been to improve the probability of survival and quality of life b training individuals to selectively respond to the environment. The research conducted during the tenure of grant NE-G-00-3-0013 was an attempt to assess the utility of physiological responses for both the prediction of individual differences in attentional capacity and the monitoring of developmental changes in attentional responsivity.

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II. Infancy Research

A. Background and rationale. Questions relating to the normal development of information processing must begin with empirical studies of the infant. The investigation of the infant is not only an attempt to demonstrate specific experimental origins of behavior (e.g., learning and personality variables) but also an attempt to identify specific predispositions which may be used as predictors of later behavioral patterns. Since the period of early infancy is characterized by a lack of meaningful verbal communication, physiological and motor responses have long been proposed as indicators of underlying psychologic processes.

Developmentally, the "learning process" may be examined as three progress processes. The first process is the ability to respond to environmental stimul If the infant does not respond to changes in the environment, no learning of behavioral self-regulation is possible. The second process is the ability to inhibit responses to inappropriate stimuli. If the organism is to adapt to the environment and survive, the infant must only respond to relevant stimuli. The third process, is the ability to respond to the temporal contingencies among stimuli; the ability to pair the presence of one stimulus which may initially have been "neutral" with another stimulus which has survival value. The first process of responding to the environment is the simplest form of attentio responsivity. It is often labeled orientation and is characterized in the infa literature by orienting reflexes which have both behavioral and physiological components. For example, a novel stimulus such as a visual display may result in the movement of the eyes and changes in heart rate. The second process associated with attentional responsivity is concerned with the organism's

ability to inhibit responses to stimuli which no longer have any importance to the organism. This is labelled habituation. Habituation is characterized by a response decrement as a function of repeated stimulus presentation. Habituation is generally very rapid to mild stimuli and often does not occur to intense or noxious stimuli. The third process is the ability to link an initially neutral stimulus with an important stimulus. This process is generally associated with classical conditioning. A series of studies were conducted with newborn infants to assess the sensitivity of heart rate response to the psychological processes of orientation, habituation, and conditioning, and whether individual differences in spontaneous heart rate actually would serve as a predictive index of individual differences in the heart rate respons used as correlates to the above psychological processes.

B. Experiments

1. Experiment I: Heart rate variability and newborn heart rate responses to illumination changes.

This study assessed heart rate response patterns in newborns to the onset and offset of a 30-second increase in illumination. The subjects were divided into two groups based on a measure of pretrial heart rate variability. Only the subjects with the high pretrial heart rate variability responded significantly to the change in stimulation. The response to onset was characterized by a significant quartic trend containing both decelerative and accelerative components. The response to offset only approached statistical significance and had a pattern similar to the onset response. Although the occurrence of systematic response patterns was related to the level of pretrial heart rate variability, this measure of autonomic lability may have been related to

influences associated with delivery and not stable individual differences. A more detailed description of this study has been published (Porges, Stamps, & Walter, 1974) and is included in Appendix A.

2. Experiment II. Heart rate responses to a simple auditory stimulus.

This study assessed in newborns the heart rate patterns in response to a 30-second moderately intense auditory stimulus (75 dbA). When the subjects were divided into two groups based on mean pretrail heart rate variability, the high variability group exhibited response patterns resembling those of matu adults. These patterns were characterized by acceleration to onset, decelera tion to offset, and decreased variability during the stimulus. The low-variability group exhibited only attenuated acceleration to onset. The results were interpreted to suggest that magnitude of pretrial heart rate variability may be used to assess neonatal responsivity to the environment. A more detailed description of this study has been published (Porges, 1974) and is included in Appendix A.

3. Experiment III: Heart rate responses as a function of age and experie

Research with newborns has seldom taken into account or tested an "experiential" model. By testing one group of neonates twice, at approximately 24 and 48 hours after birth, and a control group at approximately 48 hours after birth, the heart rate responses to auditory stimuli as a function of both age and experience could be evaluated. The findings support the hypothesis that mo neonates at approximately 48 hours after birth are physiologically capable to respond with both accelerative and decelerative heart rate responses. The fact that such responding is not as apparent in most 24-hour neonates may indicate that the influences of the delivery-medication treatment have not abated. The finding that heart rate variability was greater at 48 hours than 24 hours

parallels the heart rate responsivity and may indicate that on a within subject level, measurement of spontaneous heart rate variability may index the newborn's changing responsivity as the effects associated with the birth process dissipate. A more detailed description of this study has been published (Porges, 1974) and is included in Appendix A.

4. Experiment IV: Heart rate conditioning in newborns.

Trace conditioning was evaluated in newborn infants by examining heart rate responses to the conditioned stimulus (CS), in anticipation of the unconditioned stimulus (UCS), and in the absence of the UCS. Two sets of analyses were performed using subgroups based on pre-experimental heart rate variability and sex. Pre-experimental heart rate variability was related only to the response to the CS, with only the high-variance subjects showing a conditioned deceleration and exhibiting a change in response across trial blocks. Only the females exhibited conditioned decelerations in response to the CS and in anticipation of the UCS. In the absence of the UCS, only the experimental group as a whole responded with a deceleration. The relationship between sex and heart rate variability was examined, and the data suggest that females tend to have higher levels of heart rate variability which parallels their greater conditionability. A more detailed description of this study has been published (Stamps & Porges, 1975) and is included in Appendix A.

III. Manuscripts on methodological problems in infancy research

A. Cohort effects and apparent secular trends in infant research

At any stage of infant development the observation of behavior is dependent upon two cohort influences. The first, which is very obvious, is the infant himself. This category includes all the antecedent conditions that may

reasonably be related to the birth and early environment of the infant. The second, and often neglected, is the observer. Experimenters often assume if inter-observer reliability is demonstrated, the validity of measurement is assured. This technique merely results in a consistency of a tradition within a given style of research or laboratory. The category of the observer actually includes the experimenter's theoretical and philosophical view of the infant, often a model or set of general expectations of infant behavior.

The changing prenatal, perinatal, and neonatal environment through the years, and the various experimenter expectations of infant behavior, may interact and result in apparent secular trends in the behavior of very young infants. This manuscript emphasized two separate but interacting influences which may result in the appearance of secular trends in infant behavior: The first is the collective effect of specific environmental factors which may affect the infant's behavior and development; the second is the researcher's orientation or view of the infant.

A survey of research investigating early infant behavior during the past century exhibits a total inconsistency. The historical changes affecting prenatal, neonatal, and perinatal care may be related to the changing trends in the expectancy of early infant behavior. Although these factors may influence newborn research, they do not exist in a vacuum independent of the theoretical orientation of the experimenter. If the response potential of the newborn is to be understood, the infant cohort and the experimenter cohort must be identified and their associated influences clearly stated. A more elaborate discussion of these points have been published (Porges, 1976) and is included in Appendix B.

B. Ontogenetic comparisons

This manuscript discusses the methodological problems associated with the assessment of change in developmental research. The paper emphasizes the problems associated with response equivalence in ontogenetic comparisons and the appropriateness of traditional research designs to handle the measurement of change. The specific qualities of a response system necessary for developmental research are discussed. Various designs are critically presented and their appropriateness for developmental research is evaluated. Time-series designs are emphasized since they appear more sensitive to developmental functions (changes over time) than traditional analyses of variance. A more detailed description of the above arguments have been published (Porges, 1976) and is included in Appendix B.

C. Developmental designs for infancy research

Unique research designs are necessary to assess the rapidly changing behavioral and biological systems of developing organisms. To avoid the difficulties in sampling and the statistical complexities associated with the measurement of change, most infancy research has opted for the static designs which have been generally used in experimental psychology. Developmental functions which describe the relationship between response system and age, typically have not been adequately described by the predominant experimental designs. The application of techniques capable of identifying and describing developmental functions and the variables affecting them is the methodological challenge posed to Developmental Psychology.

Methodological problems associated with measuring change as a function of time may be historically traced to the pre-Socratic philosophy of Heraclitus.

The doctrine of constant flux, attributed to Heraclitus, precluded the possibility of assessing the same person or object twice. This is often conceptually presented by the statement that an individual could not step into the same river twice. This problem is also manifested in the attempts to assess ontogenetic change; the paradox that one could never test the same subject twice.

Not all infancy research depended upon adequate methods of evaluating behavioral change. The content justification and theoretical rationale for various areas of infancy research differs. Although all research on human development may be intricately related to some global theory of development, many researchers justify their work based upon much less demanding expectations. Research may be justified by an intrinsic interest in whether or not infants perform specific behaviors such as orienting or conditioning. This rationale necessitates few assumptions and has limited inferential value for developmental theory, since it does not necessarily relate the infant's behavior to behavior at other point on the time dimension. Other infancy research is defined by the study of psychological phenomena which have parallels later in life; the study of learning or conditioning across various ages to identify specific antecedent behavior which will be predictive of behavior later in life. This research investigates infant behavior to identify specific events or patterns of response which will aid on the prediction of later behavior and perhaps contribute to the development of intervention techniques.

The chapter stresses the methodology of studying infant behavior within a developmental approach with emphasis on description and explanation of developmental functions. Thus, the designs described in this chapter, although chosen for their possible application in infancy research, might be applicable

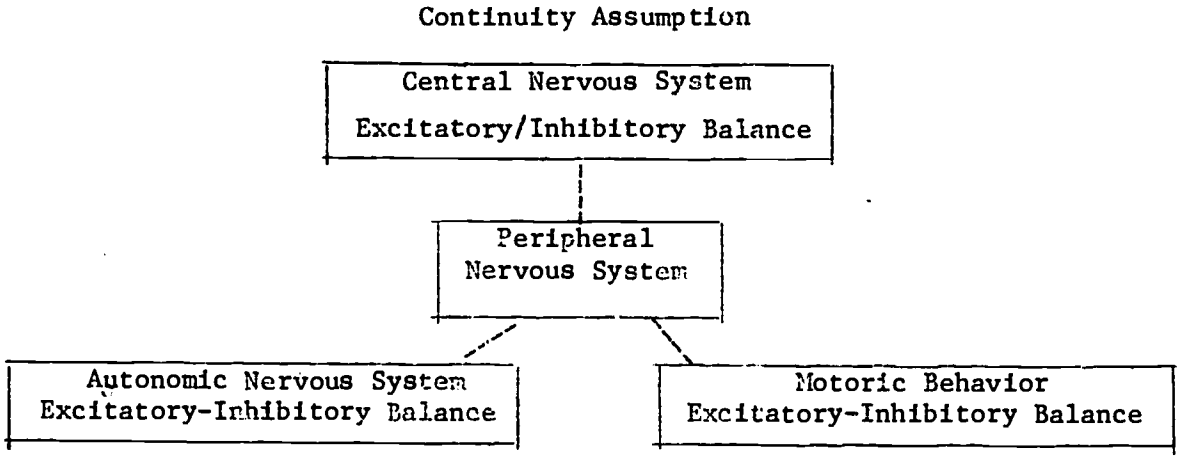
throughout the life-span. The chapter is structured to identify and describe problems related to identifying equivalent stimulus situations and behaviors necessary for developmental comparisons, to emphasize the problems associated with using analysis of variance designs to assess changes and patterns of early infant behavior, and to identify alternative methods that can be used To evaluate change over time. The complete chapter will be published (Porges, in press) and is included in Appendix C.

IV. Research on children who exhibit defective attention

A. Hyperactive children

Since a common characteristic of all definitions of hyperactivity is an inability to exhibit impulse control, this research attempted to operationalize the behavioral diagnosis of hyperactivity as quantitative individual differences in physiological activity. Two primary theoretical assumptions were made in this research: First, that not all behavior which can be classified as hyperactive is the result of neurological dysfunction (or specific brain damage); and second, that if there are identifiable neurological abnormalities such as dysfunction may be paralleled in behavior. The first assumption is related to the notion that all pathological behavior is not necessarily related to neurological pathology. Therefore, since pharmacological interventions influence the nervous system, drug treatments might be limited to individuals who exhibit a physiological dysfunction. The second assumption is a simplistic "continuity hypothesis" relat the nervous system to behavior. Thus, the goal of the research is to select subjects who are labelled as hyperactive and to partition this population according to physiological indicators of neurological function.

The model speculates that the hyperactive child's inability to control ongoing activity is a peripheral manifestation of an imbalance in central inhibitory and excitatory systems. Below is a simple sketch of this model.



As illustrated, the central nervous system has inhibitory and excitatory systems which according to the simplistic "continuity assumption" should be manifested in both the autonomic nervous system and in observable motoric behavior. In the Appendix are articles in which it is speculated that in the autonomic nervous system the inhibitory-excitatory balance might be investigated by assessing the relative contribution of the parasympathetic nervous system on the neural control of heart rate activity.

A series of studies have been conducted with hyperactive children testing the above model. Although this research question was not central to the initial proposal, NIE funds have aided in the actual research, data analysis, and/or manuscript preparation of these studies. Descriptions of the studies (Porges, Walter, Korb, & Sprague, 1975; Porges, 1976) are included in Appendix C.

B. Retarded adolescents

Defective attention is often assumed to underly the performance deficit exhibited by the retarded individual. This project was an attempt to assess the feasibility of utilizing physiological responses as correlates of individual differences in sustained attention and of identifying individual differences in spontaneous physiological activity which might be used to detect the neurological dysfunction associated the defective sustained attention characteristic of retarded individuals.

The study assessed the differences in physiological activity (heart rate and respiratory responses) during visual search. The findings of the study support the contention that retarded individuals, relative to normal subjects, exhibit physiological responses during tasks demanding sustained attention which parallel their poor performance. This study is described in detail in Appendix C (Porges & Humphrey, in press). This project, like the preceding one on hyperactive children, was not central to the initial proposal. However, NIE funds have aided in the actual research, data analysis, and/or manuscript preparation.

V. Other research.

The following are experiments conducted during the granting period that are unrelated to the central theme of the initial proposal. The NIE grant has been acknowledged since the grant funds aided in secretarial support and the summer salary of the principal investigator. Appendix D lists the journals in which these articles have been published.

A. Sex differences in performance and associated cardiac activity during a reaction time task

Reaction time performance and heart rate activity were measured in male and

female college students during a variable foreperiod reaction time task. Males showed faster reaction times, greater cardiac decelerations, and higher levels of heart-rate variability during the foreperiod. There were sex differences in the heart-rate response to the onset of the warning signal, but not in the response to the imperative signal. These results indicate that those measures of cardiac activity which have been shown previously to predict performance tend to differentiate between the sexes when there are sex differences in performance.

B. Heart rate and respiratory responses as a function of task difficulty: The use of discriminant analysis in the selection of psychologically sensitive physiological responses.

The relationship between physiological response patterns and task difficulty was investigated by evaluating heart rate and respiratory responses during a choice reaction time task with three levels of task difficulty. The data fit a two-component model of attention containing reactive and sustained responses. There were two reactive responses: An immediate deceleration which was independent of task manipulation; and a short latency response, monotonically paralleling task difficulty, which was characterized by acceleration and an increase in heart rate variability. The sustained component exhibited task dependent deceleration and a generalized reduction in heart rate variability and respiration amplitude variabiltty. A stepwise discriminant analysis was performed on the task conditions using physiological responses to determine responses sensitive to task demands. Physiological response patterns were monotonically ordered as a function of task difficulty, suggesting that this technique may have advantages for determining physiological responses most

sensitive to psychological manipulation.

C. Respiratory influences on cardiac responses during attention

The effects of respiration inhibition on cardiac responses were investigated during two attentional tasks: reaction time and visual search. The responses were partitioned into two sequential components: a short-latency (reactive) acceleration and a longer latency (tonic) component characterized by directional and stabilization changes. The reactive cardiac response components were independent of changes in respiratory activity. Respiration inhibition during the tonic interval was related to both cardiac deceleration and stabilization in the reaction time task but not during visual search.

D. Effects of prenatally administered rapid, slight variations in barometric pressure on growth and behavior in the rat.

This project was undertaken as an animal model. Pregnant women most likely encounter low barometric pressure during travel in pressurized aircraft. This project was designed to assess in an animal model the barometric effects of commonly associated with airplane travel, rapid, slight, short-duration variations in barometric pressure. Two experiments were conducted which report debilitation of rats' physiological and behavioral development as a result of prenatal exposure to daily, rapid, short duration ascents to and from a simulated altitude of 6,000 feet. In the first experiment the stressor affected body weight gain patterns and reactivity to an open field. Unlike controls, stressed males and females did not differ in body weight by 32 days of age, and fewer prenatally stressed animals explored the open field without defecating. In the second experiment, stressed animals were generally lighter than controls by 35 days postpartum, and stressed animals acquired successful climbing behavior at a later age than controls. Results may be contrasted with experiments employing much lower barometric pressures and may be mediated by generalized stress reactions.

CONTENTS OF APPENDICES

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1. Porges, S. W., Stamps, L. E., and Walter, G. F. Heart rate variability and newborn heart rate responses to illumination changes. Developmental Psychology, 1974, 10, 507-513.

2. Porges, S. W. Heart rate indices of newborn attentional responsivity. Merrill-Palmer Quarterly, 1974, 20, 231-254.

3. Stamps, L. E. and Porges, S. W. Heart rate conditioning in newborn infants: Relationships among conditionability, heart rate variability and sex. Developmental Psychology, 1975, 11, 424-431.

APPENDIX B

1. Porges, S. W. Cohort and apparent secular trends in infant research. In R. F. Riegel and J. A. Meacham (Eds.), The Developing Individual in a Changing World, Vol. II: Social and Environmental Issues. The Hague: Mouton, 1976, 687-695.

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3. Porges, S. W. Developmental designs for infancy research. In J. D. Osofsky (Ed.), Handbook of Infant Development. New York: Wiley, in press.

APPENDIX C

1. Porges, S. W., Walter, G. F., Korb, J. and Sprague, R. The influences of methylphenidate on heart rate and behavioral measures of attention in hyperactive children. Child Development, 1975, 46, 727-733.

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3. Porges, S. W. and Humphrey, M. M. Cardiac and respiratory responses during visual search in normal children and retarded adolescents. American Journal of Mental Deficiency, in press.

APPENDIX D

Bohrer, R., Schervish, M. and Sheft, J. Non-central studentized maximum a related multiple-t probabilities.

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