68-11,224

MOREAU, Athena, 1936-
THE COMPARATIVE EFFECTIVENESS OF REPEATED AUDITORY AND CUTANEOUS STIMULATION FOR THE PERSISTENCE OF RESPONSIVENESS IN THE HUMAN NEONATE.

The City University of New York, Ph.D., 1968
Psychology, experimental

University Microfilms, Inc., Ann Arbor, Michigan

The comparative effectiveness of repeated auditory and cutaneous stimulation for the persistence of responsiveness in the human neonate

by

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A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

1968

This manuscript has been read and accepted for the University Committee in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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ACKNOWLEDGEMENTS

I take this opportunity to express my deep appreciation to the members of my Doctoral Committee: to Dr. William H. Ittelson, Chairman of the Committee, for his continuous support, encouragement and understanding throughout the preparation of this dissertation; to Dr. Joseph E. Barmack for his challenging and thought-provoking response to this dissertation as well as for his invaluable guidance throughout my graduate training; and to Dr. Herbert G. Birch both for providing the conceptual framework from which this dissertation derived and for making a major contribution to my growth and development as a psychologist. In addition, thanks are extended to Dr. Gerald Turkewitz, whose insightful suggestions and critical comments were an invaluable aid at every stage of the investigation. The assistance of Mr. David Crystal, Miss Susan Fleischer and Mr. Judah Ronch in the collection and analysis of the data is also gratefully acknowledged.

This research was supported in part by the National Institute for Child Health and Human Development (HD-00719); by the Association for the Aid of Crippled Children; and by the National Association for Retarded Children.

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CHAPTER I

INTRODUCTION

The present study is concerned with an examination of the comparative effectiveness of repeated auditory and cutaneous stimulation for the persistence of certain responses in the human neonate. This focus derives from a broader concern with the problem of defining the nature of the effective stimulus environment of the newborn infant as one of the primary and essential means of understanding behavioral organization and patterning in early life.

Recognition of the importance of identifying those aspects of the objective surround to which the neonate is responsive and which therefore constitute his effective stimulus environment is based upon the view that appreciation of the psychological significance of any performance requires knowledge of the effective stimulus world of the performer (Birch, 1954; Maier and Schneirla, 1935; Schneirla, 1965). The importance of distinguishing between the geographic world of physical stimuli and the behavioral world of effective stimuli for understanding the mechanisms underlying the organization of behavior has been emphasized by Koffka (1928) and Lewin (1936). These theorists have argued that since only those features of the physical situation to which the organism is responsive can affect his behavior, identifying the organism's behavioral field in terms of effective stimulus inputs is necessary for understanding the laws of behavioral organization.

Despite the long-felt need for systematic study of neonatal afferent organization as one means of understanding behavior during early infancy, work on this problem has been sorely neglected by both developmental and child psychologists (Wohlwill, 1960). Instead, attention has been directed to the study of motor organization and differentiation during early infancy. This direction of concern is exemplified by the classical studies of Canestrini (1913; cited in Pratt, Nelson and Sun, 1930), Peiper (1924, 1925, 1928), Pratt, Nelson and Sun (1930), Jensen (1932), Irwin and Weiss (1934), Stubbs (1934) and Weiss (1934) as well as by the later work of Gesell and Amatruda (1945). Since these investigators dealt with such questions of efferent patterning as generalized vs.

localized responsiveness, frequency and intensity of response, and relationships between response systems, their findings are pertinent to the problem of output organization during infancy rather than to that of input organization.

Because the problem of the organization of afferent functioning in the neonate is multifaceted, one can with equal justification examine any of a number of its aspects, e.g. threshold phenomena in various sense modalities, the ability to discriminate among stimuli presented to a single modality or the ability to integrate multimodal information presented either simultaneously or successively. Although the thorough investigation of all of these questions is essential to a full understanding of the neonate's effective stimulus environment, such thoroughness is beyond the scope of any single experiment and a choice is therefore required. The specific aspect of sensory organization in the neonate which was selected for study in the present experiment was the differential effectiveness of stimulation of different sensory modalities.

The decision to approach the problem of defining the effective stimulus world of the infant by studying the differential effectiveness of different sensory inputs was based upon the view, derived from comparative psychology, that phylogenetic and ontogenetic differences in behavior may be understood in relation to differences in the organization and patterning of effective stimulation (Birch, 1954; Maier and Schneirla, 1935; Schneirla, 1965; Turkewitz, Gordon and Birch, 1965). This general viewpoint, which has provided a framework for the systematic examination and analysis of the sensory mechanisms underlying the organization of responsiveness of different organisms and of the same organism at different stages of development (Maier and Schneirla, 1935), has led to the formulation of a general explanatory concept in terms of the hierarchical structuring of afferent systems. According to this concept, there is an ordered relationship among input systems such that input to one sensory modality is dominant in its effectiveness for behavior over input to another sensory modality. Utilization of this concept, initially formulated by Sherrington (1906), has led several comparative and developmental psychologists (Birch, 1962; Hermelin and O'Connor, 1964; Maier and Schneirla, 1935; Schneirla, 1965), to hypothesize that the way in which behavior is organized is largely dependent upon the hierarchical ordering of the various sense modalities. Thus, the degree to which chemical, pressure, light and sound stimuli affect responsiveness is held to provide a basis for the establishment of inter- and intra-species differences in behavior (Birch, 1962; Maier and Schneirla, 1935).

Utilization of the concept of sensory-system hierarchy in the analysis of comparative behavioral data has enabled an understanding of the way in which some multifaceted behavioral functions may derive from relatively simple differences in sensory dominance relationships. Among ants, for example, apparently complex species-typical patterns of food-getting behavior are, in large part, dependent upon the relative potency of different types of stimuli for the elicitation of directed orienting responses. Those species which follow a route to food by virtue of the chemical which saturates it tend to forage collectively whereas other species who depend mainly upon visual stimuli and for whom the chemical factor is of negligible importance tend to forage individually (Maier and Schneirla, 1935). The difference in sensory-system hierarchy therefore appears to be one of the principal factors determining the nature of differences in social organization within the ant colony although this factor alone cannot account for all aspects of such organization.

In fishes, a similar relationship between afferent organization and characteristic pattern of behavior is manifest. Those fishes who have well developed chemical and tactual sensitivities are bottom feeders; those fishes who have a highly developed visual sensitivity are surface feeders (Maier and Schneirla, 1935).

Even within a given species, certain disparities in sensory-system hierarchy seem to underlie differences in behavior. For example, among different breeds of dog, the effectiveness of particular training practices is, in large part, dependent upon whether the dog is one in whom olfaction or vision is the hierarchically predominant sensory modality (Birch, 1962; Guthrie, 1960).

The comparative analysis of behavioral functions in terms of afferent-system organization has suggested an evolutionary trend in the hierarchical ordering of sensory inputs. This trend is characterized by a gradual shift in sensory dominance hierarchy from proximo- and intero-reception to teloreception (Maier and Schneirla, 1935; Schneirla, 1965; Sherrington, 1906). At lower phyletic levels, organized functions are principally based upon sensitivity to proximal and internal sources of stimulation, i.e. upon responsiveness to cutaneous, proprioceptive, visceral and chemical inputs. The phylogenetic primacy of proximal and internal input effectiveness is evidenced by the relative dominance of gustatory, chemical and proprioceptive inputs in organizing the adaptive behaviors of lower organisms (invertebrates and lower vertebrates). As one ascends the evolutionary scale, intero- and proximo-ceptor system prepotency comes to be superseded by teloceptor system prepotency. This transition is held to be a reflection of the structural and functional evolution of the nervous system. As Sherrington (1906) has pointed out, the phylogenesis of neural function is characterized by the gradual ascendency of the distance receptor systems (e.g. vision, audition). It is these latter systems which contribute most to the "uprearing" of the cerebrum. Thus, "the cerebellum is the head ganglion of the proprioceptive system" and "the cerebrum is the head ganglion of the distance receptors" (Sherrington, 1906, Pp. 346 and 348, respectively). This phylogenetic transition in neural organization is reflected in gradual increases in responsiveness to teloreceptive sources of stimulation (Schneirla, 1965).

Application of the concept of sensory-system hierarchy to the development of the individual organism suggests that, in general, proximoceptor-system prepotency is antecedent to teloceptor-system prepotency in ontogenesis as it is in phylogenesis (Birch, 1954; Coghill, 1929; Kuo, 1932). The postulation of a sequence of change from proximal to distal input predominance during the course of development receives some support from the results of developmental studies of the sensory basis of directional orienting responses in rats and kittens. Turkewitz (1966) found that the neonate rat's initial orientation to the nest region of his cage is dependent upon the presence of tactile and olfactory cues whereas his later orientation to the nesting area entails responsiveness to visual sources of stimulation. In a series of investigations of orienting behavior in kittens, Rosenblatt, Turkewitz, and Schneirla (1962) showed that directional responses which during the early postnatal period are based primarily upon tactile, thermal and olfactory stimuli subsequently come to be elicited by visual stimuli.

The hierarchical organization concept has also been applied to the analysis of the behavioral ontogenesis of man although the nature of the relationship between sensory-system hierarchy and developmental changes in human behavior has not as yet been assessed. Proponents of the general hypothesis (Birch, 1962; Schneirla, 1965) have postulated that intero- and proximo- receptive inputs predominate over teloreceptive inputs in determining responsiveness during early infancy. They have further hypothesized that in the course of development, the dominance of proximoceptive and visceral sensitivity is gradually replaced by the dominance of auditory and visual sensitivity until a stage is reached in which the complex patterning of behavior is preeminently organized around information derived from the distance receptors. The behavior patterns initially organized around proximal inputs are maintained and elaborated on the basis of the growing utilization of teloreceptor inputs. Hence, the young infant is considered to be primarily responsive to visceral, tactile and interoceptive stimuli whereas the older child and the adult are primarily responsive to auditory and visual stimuli.

Application of the principle of sensory-system hierarchy to the analysis of clinical problems has led several workers to a consideration of some of the behavioral consequences of the inadequate development of appropriate hierarchical relationships among afferent systems. Birch (1962), for example, has hypothesized that since reading requires the organization of a hierarchical set of relations among sense systems in which the teloreceptor systems (especially the visual) are dominant, the failure to develop such dominance may be one of the mechanisms underlying reading disability. Similarly, Goldfarb (1956) and Hermelin and O'Connor (1964), who found that in contrast to normal children, schizophrenic and autistic children make contact with their environment through the proximal rather than the distance receptor channels, have suggested that the failure to shift from proximoreceptor to teloreceptor prepotency may, at least in part, underlie certain types of aberrant behavior. If this is indeed the case, then the examination of sensory dominance relations may prove to be useful for the diagnosis and evaluation of certain behavioral disorders in children.

In spite of the growing recognition of the importance of studying hierarchical afferent relations in the human organism as one means of elucidating the mechanisms underlying his behavioral organization and development, information on the nature of age-specific input hierarchies is conspicuously absent from the literature. The present investigation represents an attempt to begin to fill this void by subjecting one aspect of the question of sensory-system prepotency in the human neonate to experimental scrutiny.

Consideration of the specifics of the question to which the current investigation is addressed raises several problems. The first of these derives from the fact that there are many sense modalities the complete study of which requires a program of research rather than a single experiment. Consequently, a choice had to be made. Both theoretical relevance and experimental feasibility determined the choice of input systems to be studied in the current investigation. In accordance with Sherrington's (1906) delineation of three main classes of input — intero-, proximo- and telo-receptor — and in view of the difficulty of measuring and controlling interoceptive sources of stimulation, a proximoreceptor (cutaneous) and a teloreceptor (auditory) system were selected for comparative study.

A second problem involved the choice of a particular strategy or model to be used in examining the nature of hierarchical relations between and among sense systems. Although several alternatives were available, it should be noted that the various possibilities are not necessarily equivalent to one another. One possibility was a competition or conflict model in which preferential responsiveness to simultaneous presentations of stimuli to different sense modalities would be studied. Another strategy would involve a comparison of absolute and of difference thresholds between and among the different sensory systems. The modality differences in threshold could then be related to stimulus values and changes normally available in the newborn's environment. A third model and the one selected for use in the present investigation was a habituation or resistance-to-change model wherein the comparative persistence of responsiveness to repeated presentations of stimuli to different sense modalities was studied.* This model was chosen because study of the durability of effectiveness of afferent input would provide information concerning the nature of the neonate's effective stimulus environment and differences between the durability of effectiveness of various inputs would provide information concerning the nature of hierarchical relations among sense systems.

*The term "habituation", as used throughout this paper, refers to an observed decrease in the frequency of response consequent upon repeated stimulation and does not imply a specific mechanism of response decrement.

Recent findings of a consistent effect of repeated stimulation on neonatal behavior enable the systematic examination of the degree to which repeated presentations of stimuli to different sense modalities are differentially effective for the persistence of responsiveness in the newborn infant. The results of numerous investigations indicate that, in the neonate as in the older organism, repeated presentation of any stimulus that is initially effective for the elicitation of a given response results in a diminution of response. Although such a modification of responsiveness has been described in the early literature on child development (Disher, 1934; Forbes and Forbes, 1927; Peiper, 1925), it has only recently been subjected to systematic study. In a series of investigations of the neonate's responsiveness to olfactory stimulation, Lipsitt and his co-workers have demonstrated reductions in general bodily activity, in respiratory irregularities and in leg withdrawals to repeated presentations of acetic acid, phenylethyl alcohol, anise oil and tincture asafoetida (Engen and Lipsitt, 1965; Engen, Lipsitt and Kaye, 1963).

Using non-nutritive sucking as an indicator of the infant's responsiveness to various types of stimuli, Bronshtein, Antonova, Kamenetskaya, Luppova and Systova (1958) have reported that the administration of a tone, a chemical, an air stream or a light to an infant at a time when he was sucking initially reduced his sucking activity but successive stimulus presentations no longer resulted in a decrease in sucking activity. Repeated auditory stimulation was reported to be least effective and repeated olfactory stimulation most effective in so modifying the infant's initial response. Evlauation of these findings, however, is rendered difficult if not impossible by virtue of the gross deficiencies in the experimental method and procedures used as well as in the analysis, interpretation and presentation of data (Brackbill, 1962). Since Bronshtein _et al_ did not specify whether either the stimulus durations or the intertrial intervals were the same for the various types of stimuli used, it is not possible to compare the stimuli meaningfully. In addition, Bronshtein's data indicate that only 34% of the infants under 18 days of age showed a reduction in sucking activity to the initial presentations of the auditory stimulus. Since no baseline data with which to compare this 34% is presented in the report, it is not possible to determine whether even the initial presentations of the auditory stimulus were effective for reducing ongoing sucking activity. Subsequent attempts to replicate Bronshtein's findings with respect to auditory stimulation were successful in one case (Hickman, 1964) but unsuccessful in another (Kaye and Levin, 1963). These apparently contradictory results cannot be resolved since both the stimuli and the procedures used differed in the two studies.

The effects of repeated stimulation on several other types of response have also been studied. Prechtl (1958), for example, found that the frequency of directed head-turning to cutaneous stimulation is reduced if the same stimulus is applied to the same spot. Similarly, Bridger (1961), Bridger and Reiser (1959) and Bartoshuk (1962a, 1962b) found a cessation of startle and of cardiac acceleration to repeated tactile (airstream to abdomen) and acoustic (80 or 85 db, 400 or 500 cps) stimulation and Leventhal and Lipsitt (1964) reported a decrease in stabilimeter movement, respiratory activity and frequency of leg withdrawals to successive presentations of a pure tone.

The results of the abovementioned studies indicate that the effectiveness of various afferent inputs for neonatal behavior may be modified as a consequence of repeated stimulus presentations. The finding of a relationship between modification of response and frequency of stimulation in the young infant enables utilization of the habituation model for the comparative analysis of the durability of effectiveness of repeated proximoreceptor and teloreceptor stimulation.

In the present experiment, the rate of response decrement to a repeatedly presented cutaneous (proximoreceptor) stimulus was compared with that to a repeatedly presented auditory (teloreceptor) stimulus. The following hypothesis, derived from hierarchical organization theory, was tested: Given an initial equivalence of arousal properties of a cutaneous and an auditory stimulus, the number of trials to manifest a decrement in the frequency of response will be greater for repeated presentations of the cutaneous stimulus than for repeated presentations of the auditory stimulus.

CHAPTER II

METHODOLOGY

The development of an appropriate methodology for studying modality differences in the rate of response decrement to repeated presentations of the same stimulus was contingent upon careful consideration of the several factors *other than type of stimulus* (i.e. cutaneous or auditory) which might affect temporal changes in input effectiveness. One such factor is that of *initial* level of stimulus effectiveness. The results of numerous investigations have shown that the rate of decrement of response to a repeatedly applied stimulus is, in large part, a function of the extent to which the initial application of the stimulus is effective for the elicitation of a response (Bartoshuk, 1959; Bronshtein *et al*, 1958; Harris, 1943; Martin, 1964; Prechtl, 1958). Since an intense stimulus is initially more effective than a weaker stimulus, its loss of effectiveness upon repeated stimulation is less rapid than is the case for a weaker stimulus. The finding of differences between modalities in the rate of response decrement in those experiments in which the stimulus values have been arbitrarily selected could therefore be attributed to differences in initial effectiveness consequent upon intensity differences rather than to modality differences in the temporal course of effectiveness *per se*. To eliminate this source of contamination, it is necessary to establish the equivalence of initial effectiveness of the various stimuli. In the present experiment, the selection of intensity values of the cutaneous and auditory stimuli was based upon the empirically demonstrated equivalence of initial effectiveness of the two stimuli. This equivalence was established in a "stimulus standardization" study in which the effect of given intensities of a cutaneous and of an auditory stimulus on the amount of heart rate change in the human neonate was measured. The results of this study enabled the selection of a suprathreshold cutaneous and a suprathreshold auditory stimulus which were equally effective for the initial elicitation of heart rate change. The cutaneous stimulus so selected was contact with a No. 12 round camel's hair brush which was applied to the infant's left cheek midway between the pinna of the ear and the corner of the mouth. The Auditory stimulus was a white noise presented at a distance of two inches from the infant's left ear. The intensity of the sound was 90 db (re 0.0002 microbar, sound pressure level) when measured at the ear. Stimulation by the No. 12 brush resulted in a mean change in heart rate from the pre- to the post-stimulus periods of 6.0 beats per min. and stimulation by the 90 db sound resulted in a mean change in heart rate of 7.8 beats per min. This difference between stimuli in mean amount of heart rate change was not statistically significant ($p > .05$, $t = .92$, $df = 37$). Of the

19 infants who were administered the No. 12 brush, 17 exhibited a change in heart rate and of the 20 Ss who were administered the 90 db sound, 19 exhibited a change in heart rate. This difference between stimuli in the proportion of infants manifesting a change in heart rate was not statistically significant ($p > .05$, χ^2 corrected for continuity = 0, df = 1).

A second factor which has been found to affect the time course of changes in the effectiveness of input is the state of the organism. The rate of habituation of response to repeated stimulation is dependent upon whether the organism is awake or asleep, active or inactive and hungry or satiated (Bridger, 1961, 1962; Bridger and Reiser, 1959; Sharpless and Jasper, 1956). Since these differences in state modify the effects of repeated stimulation, the comparison of temporal changes in effectiveness between sensory modalities requires that organismic state be either held constant or made comparable under the various conditions of stimulation. To handle this problem in the present experiment, the following controls were instituted:

1) Feeding state and time of day during which testing was conducted were held constant. All infants were tested 50-75 minutes prior to the regularly scheduled 9:30 AM feeding.

2) Male infants were excluded from the sample because of uncontrolled alterations of state consequent upon circumcision, routinely

performed at the hospital from which the present sample was selected when the infant is between 24 and 48 hours old.

3) Infants who cried at any time during the course of testing were omitted from the sample in order to maintain arousal and activity levels as constant as possible.

4) Although some of the infants were asleep during testing, the proportion of asleep to awake infants was comparable under the two conditions of stimulation. Judgments as to whether the infant was awake or asleep were based upon whether the eyes were open or closed. Of the 20 infants who received cutaneous stimulation, 9 were awake and 11 were asleep; of the 20 infants who received auditory stimulation, 14 were awake and 6 were asleep ($p > .05$, $X^2 = 1.64$, $df = 1$).

5) Age at time of testing was comparable under the two conditions of stimulation. Infants receiving cutaneous stimulation ranged in age from 27 to 64 hours (mean = 40.8 hrs.) and infants receiving auditory stimulation ranged in age from 24 to 71 hours (mean = 39.8).

Two additional factors known to affect the rate of habituation to repeated stimulation are the time interval between stimulus presentations and the stimulus duration. In general, the shorter the interstimulus interval and the longer the stimulus duration, the more rapid the rate of response decrement (Bridger, 1961; Harris, 1943; Hickman, 1963; Martin, 1964; Prechtl, 1958;

Sharpless and Jasper, 1956). In the present experiment, these factors were controlled by utilizing the same interstimulus interval and the same stimulus duration for the two conditions of stimulation.

The development and application of an appropriate methodology for studying modality differences in habituation rate requires, in addition to the aforementioned considerations, a consideration of the factors involved in the choice of response system and specific response indicator to be used. Although we could choose to study either autonomic or somatic responsiveness, there is no reason to assume that the effects of repeated stimulation are identical for the two types of response system. To permit the examination of possible differences in the rate of response decrement between the two types of system, one somatic and one autonomic response indicator were selected for study in the present experiment. Since changes in heart rate can be reliably elicited in the human newborn by both cutaneous and auditory stimulation (Bartoshuk, 1962a, 1962b, 1964; Bridger, 1961, 1962; Bridger and Reiser, 1959; Davis, Crowell and Chun, 1965; Lipton and Stinschneider, 1964) it was chosen as the autonomic measure. The somatic response indicator selected was the direction of lateral conjugate eye movement. Earlier studies have shown that the typical eye movement response of the neonate to laterally presented cutaneous and auditory stimuli of the type and intensity utilized here is a turn in the direction of the stimulus (Turkewitz, Birch, Moreau, Levy, and Cornwell, 1966; Turkewitz, Moreau, and Birch, unpublished). Therefore, only those conjugate eye movements which were ipsilateral to the locus of stimulation were counted as responses.

CHAPTER III

EXPERIMENTAL DESIGN AND PROCEDURE

Experimental design. Infants were assigned to one of two conditions of stimulation (n = 20 in each condition). The first condition was used to assess the effect of repeated cutaneous stimulation on cardiac and eye movement responsiveness and the second condition was used to assess the effect of repeated auditory stimulation on such responsiveness.

Testing conditions. Testing took place in a neonatal laboratory located adjacent to the nurseries. The ambient noise level in the laboratory was 59 db ± 3 db (sound pressure level). Lighting was provided by an overhead incandescent lamp. To insure constancy of illumination, the window shades were drawn prior to testing.

Experimental procedure. Each infant was wheeled into the laboratory in her own bassinet, placed in the supine position and swaddled. The infant's head was placed in a holder which, when adjusted to conform to the head, eliminated movements in the coronal plane.

To enable presentation of the auditory stimulus, a speaker, mounted on an adjustable rod, was placed in the bassinet and positioned so that the cone was two inches from the pinna of the S's left ear. To insure consistency of locus of presentation of the cutaneous stimulus, an adhesive strip having a .5 inch diameter cutout was placed on the infant's left cheek midway between the pinna of the ear and the corner of the mouth. The speaker and the adhesive strip were used for all Ss regardless of the stimulus condition to which they had been assigned.

Both the heart rate and the eye movement responses were recorded polygraphically. To obtain such recordings of cardiac rate, two EKG electrodes were fixed onto the infant's chest. To obtain EOG recordings of lateral conjugate eye movements, surface electrodes were fixed onto the outer canthus of each eye.

The experimental procedure consisted of 40 successive presentations of either the 90 db auditory stimulus (to Ss assigned to the auditory stimulus condition) or the No. 12 camel's hair brush (to Ss assigned to the cutaneous stimulus condition). Presentation of the auditory stimuli was automated and that of the cutaneous stimuli was manual. The duration of each stimulus was one second and the interstimulus interval was eight seconds. For the auditory stimuli, the timing of the stimulus duration and the interstimulus interval was automated. For the cutaneous stimuli, the duration and interstimulus interval were timed by means of an automatically presented one second pure tone signal (via earphones) to the experimenter every eight seconds. This signal was not audible to the infant. The experimenter presented the cutaneous stimulus concurrently with receipt of the pure tone signal.

Apparatus. The white noise stimulus was produced by a Grason-Stadler Noise Generator, fed through a Grason-Stadler Electronic Switch (rise-decay time $<$ 0.5 ms) and attenuated by a Hewlett-Packard Attenuator Set. The signal was then amplified by a Hewlett-Packard Amplifier and fed through a Lafayette SK-214 Ultra High Compression Lens Tweeter. The stimulus duration and the interstimulus interval were programmed by a Grason-Stadler Interval Timer.

One channel of an Offner Type R Polygraph was used to record lateral conjugate eye movements and another to record heart rate. Two additional channels were used to record the onset and duration of the cutaneous and the auditory stimuli. The event marker for the cutaneous stimuli was activated by the experimenter, who squeezed the bulb end of a pneumograph concurrently with the presentation of the stimulus. The event marker for the auditory stimuli was electronically activated.

Scoring procedure. The effect of stimulation on heart rate was assessed by comparing the heart rate during the pre-stimulus period with that during the post-stimulus period. The pre-stimulus rate was determined by measuring the time elapsed between the first and the seventh heart beats immediately prior to the onset of the stimulus and the post-stimulus rate was determined by measuring the time elapsed between the first and seventh heart beats immediately following the onset of the stimulus. These time measures were then converted into rates in terms of number of beats per minute. A change in heart rate was defined as a difference of two or more beats/min. between the pre- and the post-stimulus periods. This criterion of two rather than one beat/min. was used because the error of measurement was ± 1 beat/min. The direction of change in heart rate from the pre- to the post-stimulus periods, i.e. acceleration or deceleration, was assessed by subtracting the pre-stimulus rate from the post-stimulus rate and noting whether the sign of this difference was positive, indicating acceleration, or negative, indicating deceleration.

The effect of stimulation on ipsilateral conjugate eye movement was assessed by determining whether an eye turn in the direction of the stimulus occurred within two seconds following the onset of the stimulus. When such an eye movement occurred, it was counted as a response only if it was the first movement made within the two second period.

Heart rate changes and eye movement responses were both independently scored by two scorers, neither of whom knew the condition of stimulation under which the record had been obtained. The inter-scorer agreement was 95% for heart rate and 77% for eye movement. In cases of disagreement between scorers, decisions were made by a third scorer and the results of this "composite decision" were used in computing the data.

Subjects. The sample studied consisted of 40 female neonates who were resident in the well-baby nurseries of the Bronx Municipal Hospital Center. All of the subjects were normal and healthy as determined by 1) a birth weight of over 2.5 kg, 2) an Apgar score of 7 or higher (Apgar, Holaday, James, Weisbrot, and Berrien, 1958), 3) a pediatric evaluation resulting in the classification of the baby as a "well-newborn" and 4) no recorded evidence of abnormality during the mother's pregnancy or labor and no complications of delivery.

The distribution of subjects in each condition of stimulation according to Apgar score, type of delivery and method of feeding are presented in Table 1. The infants tested under the two conditions of stimulation did not differ significantly with respect to any of these characteristics.

Table 1. Characteristics of the sample

Characteristic	Stimulus Condition Cutaneous (n = 20) frequency	Auditory (n = 20) frequency
Apgar Score		
7	0	1
8	0	2
9	10	9
10	10	8
Type of delivery		
Normal spontaneous	12	15
Forceps	8	5
Method of feeding[1]		
Bottle	19	19
Breast	1*	1*

*The low incidence of breast-fed infants reflects the prevalent mode of infant care in this hospital rather than any selection bias.

[1] Since the first post-natal feeding occurs at the age of 24 hours, all Ss had been fed at least once prior to testing.

CHAPTER IV

RESULTS

In order to determine the relative effectiveness of repeated cutaneous and repeated auditory inputs for the persistence of responsiveness in the neonate, we compared the effect of repeated stimulation of these modalities on the frequency of response. However, before this comparison could be made, it was necessary to determine whether the infants being studied for habituation in the present experiment responded to initial presentations of the auditory and cutaneous stimuli in the same manner as had the group of infants used for the stimulus standardization. Furthermore, since directional eye movement was not used as a criterion measure in the stimulus standardization study, it was necessary to determine whether the auditory and cutaneous stimuli which had been found to be initially equivalent for heart rate change, were also equivalent for the eye movement response. The equivalence in initial effectiveness of the cutaneous and auditory stimuli for the infants in the main investigation was therefore assessed. This was done by comparing the frequency of both heart rate changes and ipsilateral conjugate eye movements made to the first five presentations of the cutaneous stimulus with that made to the first five presentations of the auditory stimulus.

Effect of initial auditory and cutaneous stimulation on the frequency of heart rate change, heart rate acceleration and heart rate deceleration. The cutaneous and auditory stimuli did not differ in the effectiveness with which they initially elicited heart rate changes. As may be seen in Table 2, there was no significant difference between the two types of stimuli with respect to the frequency with which changes in heart rate occurred to the initial block of stimulus presentations (trials 1-5).

Table 2. Frequency of heart rate change, heart rate acceleration and heart rate deceleration to initial auditory and cutaneous stimulus presentations (trials 1-5)

Stimulus	$\bar{X}$ no. of heart rate changes	s.d.	$\bar{X}$ no. of accelerations	s.d.	$\bar{X}$ no. of decelerations	s.d.
Auditory	3.66	1.06	2.38	1.35	1.28	.96
Cutaneous	3.83	.91	2.15	.99	1.68	.92
p*	NS		NS		NS	

*Two-tailed Mann-Whitney U tests

Since a change in heart rate can be either an acceleration or a deceleration, the analysis of the frequency of change *per se*, independent of its direction, could obscure differences between stimuli in the frequency of elicitation of either heart rate increase, heart rate decrease, or both. To determine whether the initial cutaneous and auditory stimulus presentations were equivalently effective for the elicitation of both cardiac acceleration and cardiac deceleration, the heart rate change data were analyzed with respect to the character of the change. No significant differences between the two stimuli were found in the frequency with which either accelerations or decelerations occurred in response to the initial block of stimulus presentations (trials 1-5).

Effect of initial auditory and cutaneous stimulation on the frequency of ipsilateral conjugate eye movement. The cutaneous and auditory stimuli did not differ in the effectiveness with which they initially elicited ipsilateral conjugate eye movements. As may be seen in Table 3, the initial presentations of the cutaneous stimulus produced

Table 3. Frequency of ipsilateral conjugate eye movement to initial auditory and cutaneous stimulus presentations (trials 1-5)

Stimulus	$\overline{X}$ no. of responses	s.d.
Auditory	1.85	1.39
Cutaneous	1.65	1.53
p*	NS	

* Two-tailed Mann-Whitney U test

approximately the same number of eye movement responses which were in the direction of the stimulus as did the initial presentations of the auditory stimulus.

Since the cutaneous and auditory stimuli were initially equivalent in the effectiveness with which they elicited 1) ipsilateral conjugate eye movement, 2) heart rate change, 3) heart rate acceleration and 4) heart rate deceleration, it was possible to examine the differences in the temporal course of effectiveness between the two types of stimuli. The effect of repeated stimulation on the frequency of response was assessed by means of a sequential analysis. This was done by dividing the 40 stimulus trials into eight blocks of five trials each and then contrasting the results from the first block of trials (trials 1-5) with those from each of the seven subsequent blocks of trials. The criterion for response decrement was the occurrence, in a subsequent trial block, of a significant decrease in the frequency of response. The sequential analyses were done for each stimulus modality separately.

The data derived from the two indicator measures were each subjected to two types of analysis. The first was a magnitude analysis and involved a consideration of the amount of decrease in the frequency of response from the first to each subsequent trial block. Since the amount of decrease in the frequency of response in any trial block could be either the unique contribution of a few individuals in the group or a characteristic feature of the group as a whole, a second type of analysis was performed. This analysis was based upon the categorization of infants in accordance with whether they exhibited a decrease, an increase or no change in the frequency of response from the first to each subsequent trial block.

Effect of repeated auditory and cutaneous stimulation on the frequency of ipsilateral conjugate eye movement. Repeated presentation of the auditory stimulus resulted in a decrease in the frequency of ipsilateral eye movement responses. This was manifested by a gradual reduction in the frequency of ipsilateral responding from the first to the third trial block (Table 4, Figs. 1 and 2) with a significant decrease in the frequency of ipsilateral eye movement first occurring in the third block of trials (Table 4).

Table 4. Frequency of ipsilateral conjugate eye movement (Auditory Stimuli)

Trial block	$\overline{X}$ no. of responses	s.d.	$\overline{X}$ amount of decrease from first trial block	T^*	n	p^{**}
1	1.85	1.39	——			
2	1.75	1.41	.10	33.0	12	NS
3	.65	.67	1.20	3.5	14	$< .005$

*Wilcoxon matched-pairs signed-ranks tests

**One-tailed tests

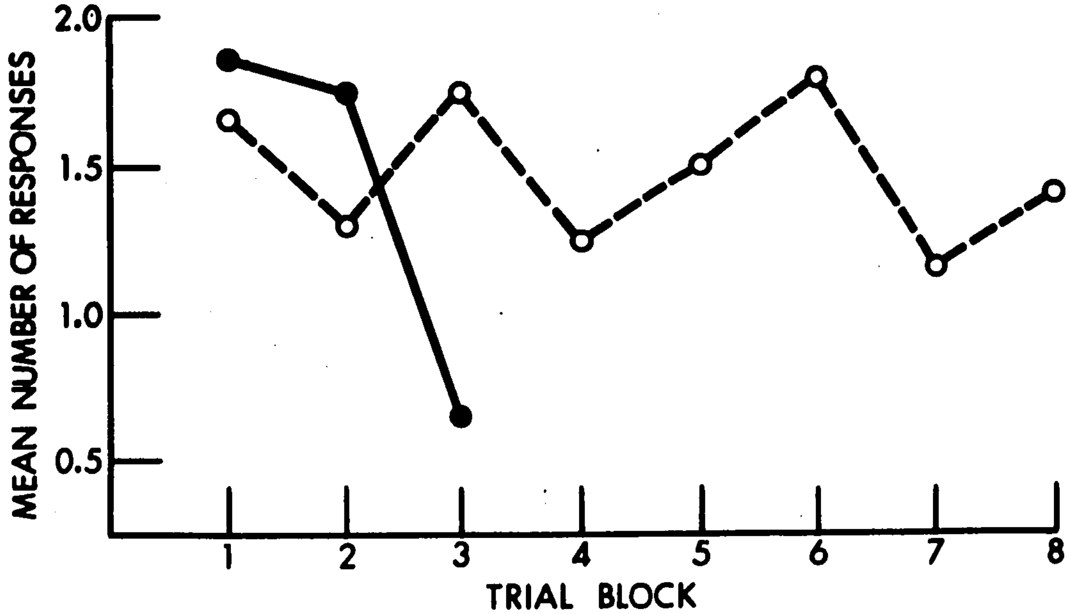

Fig. 1. Frequency of ipsilateral conjugate eye movement.

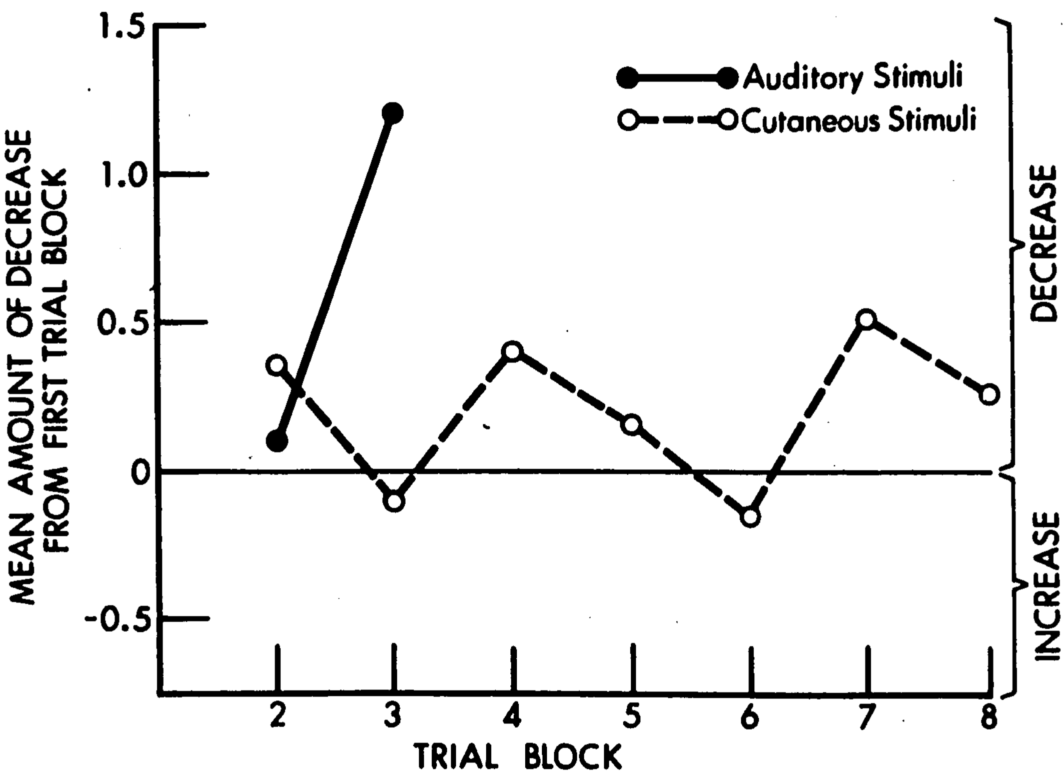

Fig. 2. Decrease in frequency of ipsilateral conjugate eye movement.

In contrast to the reduction in effectiveness of auditory stimulation, repeated presentation of the cutaneous stimulus did not result in a systematic decrease in the frequency of ipsilateral eye movement responses. As the data presented in Table 5 and in Figure 1 show, the number of eye movement responses remained relatively

Table 5. Frequency of ipsilateral conjugate eye movement (Cutaneous Stimuli)

Trial block	$\bar{X}$ no. of responses	s.d.	$\bar{X}$ amount of decrease from first trial block	T*	n	p**
1	1.65	1.53	—			
2	1.30	1.56	.35	31.0	14	NS
3	1.75	1.52	-.10[1]			
4	1.25	1.41	.40	49.0	16	NS
5	1.50	1.28	.15	31.5	12	NS
6	1.80	1.40	-.15[1]			
7	1.15	1.22	.50	31.0	14	NS
8	1.40	1.23	.25	31.0	12	NS

*Wilcoxon matched-pairs signed-ranks tests

**One-tailed tests

[1]A negative value indicates an increase.

constant throughout the course of repeated cutaneous stimulation. In none of the trial blocks was there a significant decrease in the frequency of response (Table 5). Moreover, in two of the trial blocks (blocks three and six), a small (non-significant) increase was found (Table 5 and Fig. 2).

When the data were analyzed in terms of the number of infants who exhibited a decrease, an increase or no change in the frequency of ipsilateral eye movement responses from the first block of trials, the findings paralleled those obtained from the magnitude analyses. By the third trial block, auditory stimulation had resulted in a significantly greater number of infants exhibiting a decrease than exhibiting an increase in the frequency of response (Table 6). On the other hand, the distribution of Ss showing decreases and increases

Table 6. Distribution of Ss exhibiting a decrease, an increase and no change in frequency of ipsilateral conjugate eye movement from the first trial block (Auditory Stimuli)

	Number of Ss showing			
Trial block	Decrease	Increase	p*	No change
2	7	7	NS	6
3	12	1	.002	7

*One-tailed binomial tests

in the frequency of response to cutaneous stimulation was essentially random (Table 7). In 4 of the 7 trial blocks, more infants manifested a decrease in the frequency of response than manifested an

Table 7. Distribution of Ss exhibiting a decrease, an increase and no change in frequency of ipsilateral conjugate eye movement from the first trial block (Cutaneous Stimuli)

	Number of Ss showing			
Trial block	Decrease	Increase	p*	No change
2	10	4	NS	6
3	6	7	—	7
4	10	6	NS	4
5	6	6	NS	8
6	7	8	—	5
7	9	5	NS	6
8	7	5	NS	8

*One-tailed binomial tests

increase; in 2 trial blocks more infants manifested an increase than manifested a decrease; and in 1 trial block the same number of infants manifested a decrease as manifested an increase. For none of the trial blocks was a significant difference obtained between the number of Ss exhibiting a decrease and the number exhibiting an increase in the frequency of ipsilateral eye movement responses (Table 7).

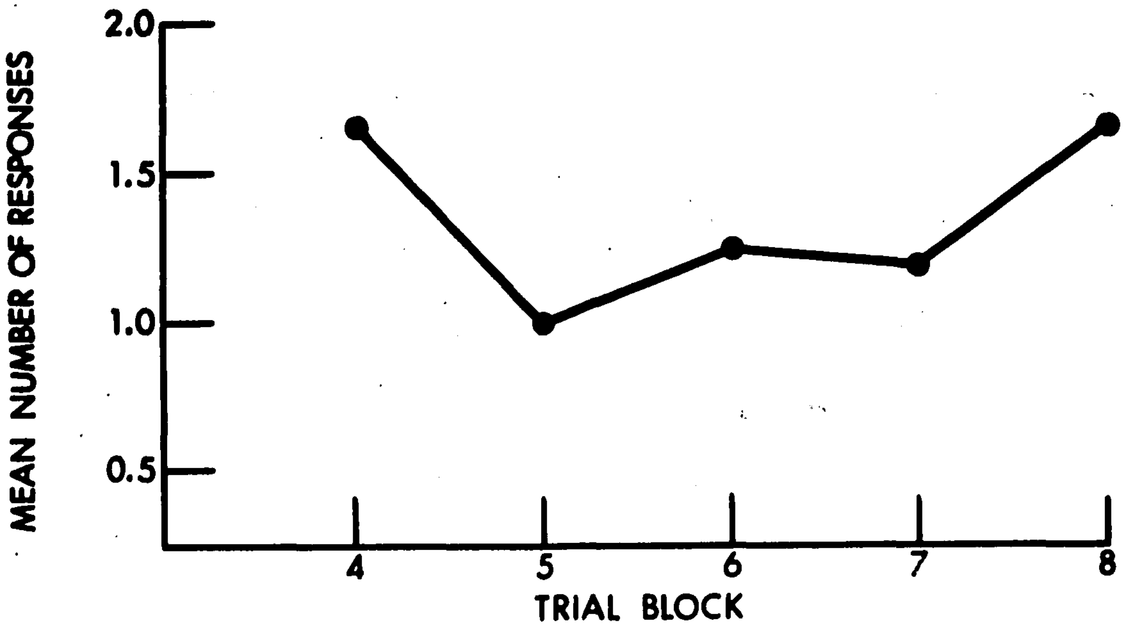

Fig. 3. Frequency of ipsilateral conjugate eye movement after criterion for response decrement had been reached. (Auditory Stimuli)

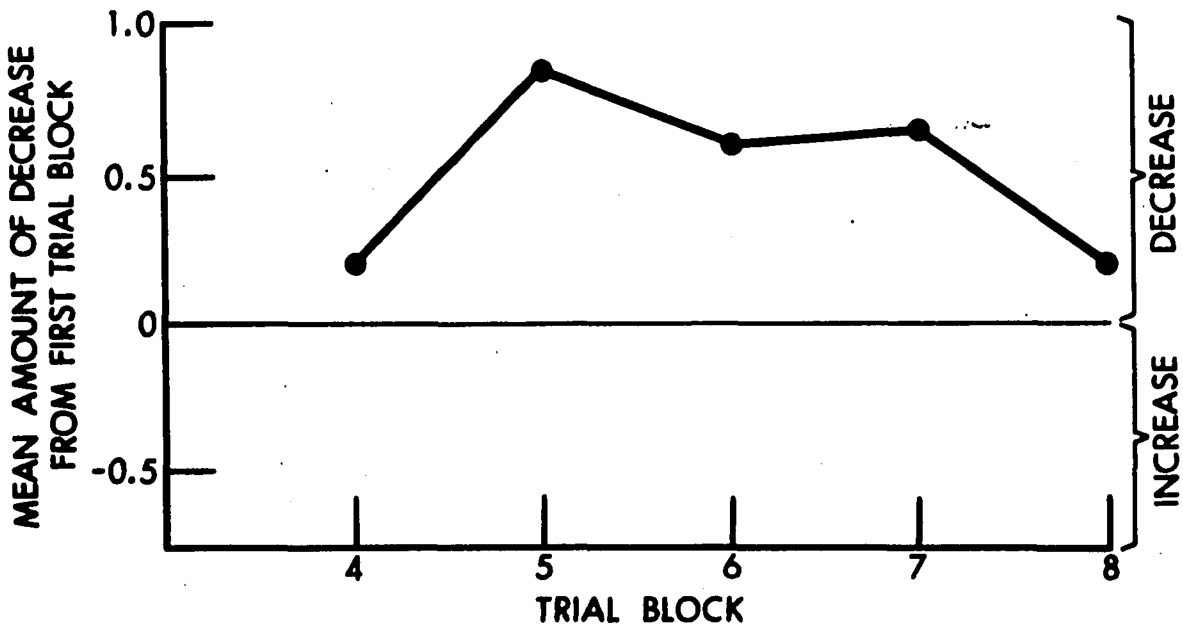

Fig. 4. Decrease in frequency of ipsilateral conjugate eye movement after criterion for response decrement had been reached. (Auditory Stimuli)

Analysis of the distribution of infants who exhibited decreases and increases in the frequency of ipsilateral eye movement responses to the auditory stimuli from the first to the last five trial blocks yielded results which paralleled those obtained from the magnitude analyses. In the fifth and sixth blocks of trials the number of infants who manifested a decrease in the frequency of response was significantly greater than the number of infants who manifested in increase; in the other trial blocks, the number of infants who manifested a decrease did not differ significantly from the number who manifested an increase (Table 9).

Table 9. Distribution of Ss exhibiting a decrease, an increase and no change in frequency of ipsilateral conjugate eye movement after criterion for response decrement had been reached

(Auditory Stimuli)

	Number of Ss showing			
Trial block	Decrease	Increase	p*	No change
4	7	6	NS	7
5	12	4	.04	4
6	10	1	.01	9
7	9	5	NS	6
8	8	7	NS	5

*One-tailed binomial tests

Effect of repeated auditory and cutaneous stimulation on the frequency of heart rate change. Analysis of the decrease in the frequency of heart rate change during the course of repeated stimulation revealed a differential effect of auditory and cutaneous inputs which was opposite to that obtained for the eye movement response. Repeated presentation of the cutaneous stimulus was effective in reducing the frequency of heart rate change whereas repeated presentation of the auditory stimulus was not systematically effective in reducing the frequency of heart rate change. A significant reduction in the frequency of heart rate change to the cutaneous stimulus was found early in the stimulus series, i.e. by the second block of trials (Table 10, Fig. 5). To the auditory stimulus, on the

Table 10. Frequency of heart rate change

(Cutaneous Stimuli)

Trial block	$\bar{X}$ no. of heart rate changes	s.d.	$\bar{X}$ amount of decrease from first trial block	T*	n	p**
1	3.83	.91	—			
2	3.17	1.21	.66	39	17	.04

*Wilcoxon matched-pairs signed-ranks test

**One-tailed test

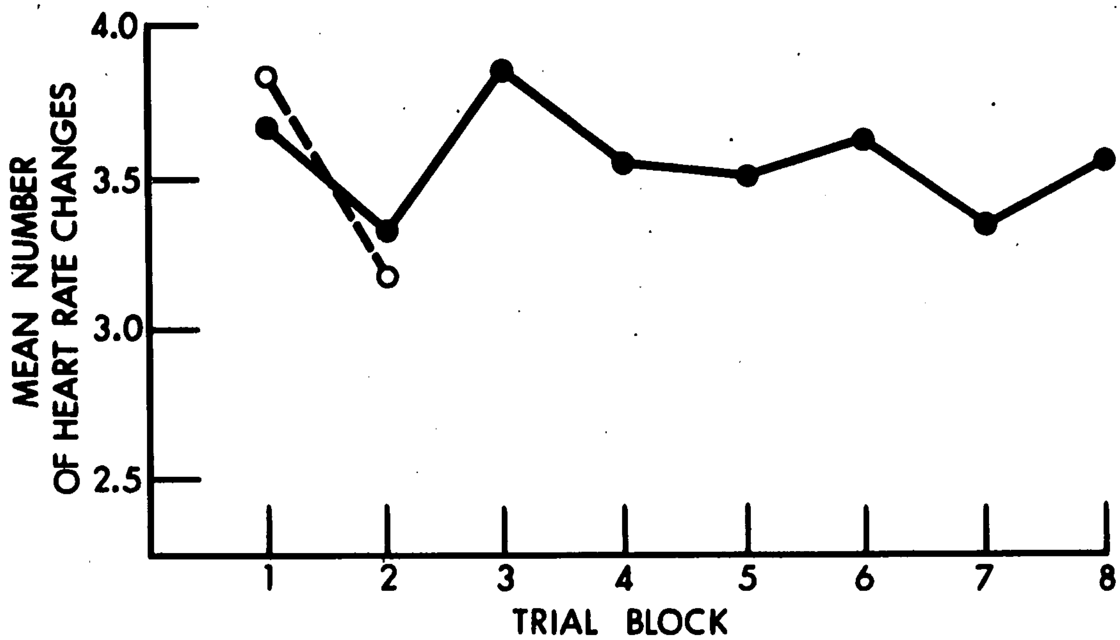

Fig. 5. Frequency of heart rate change.

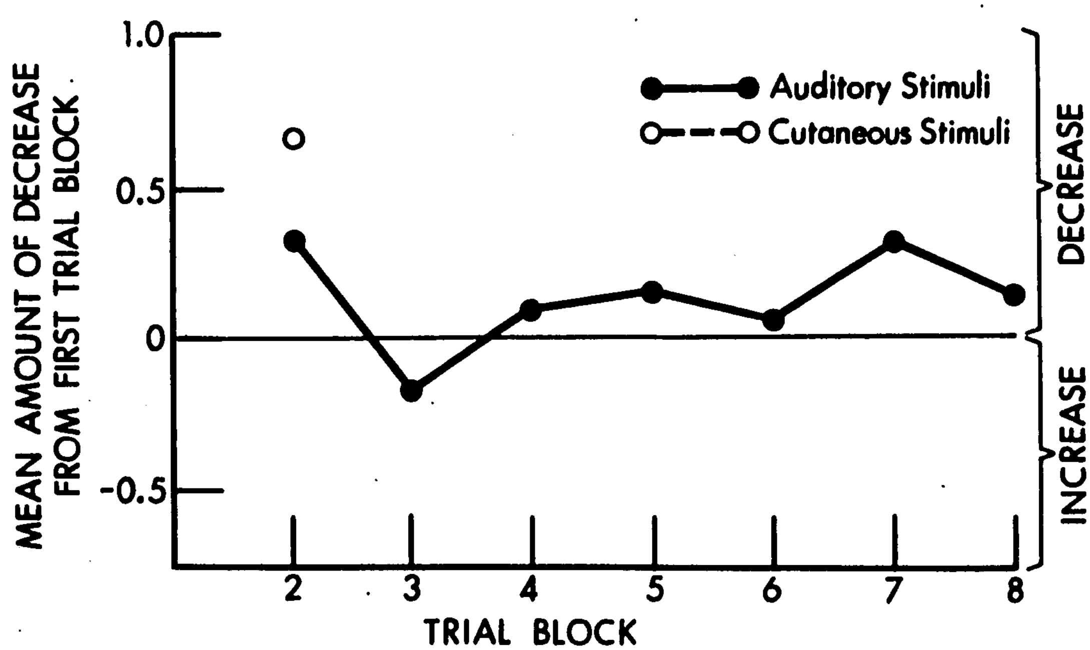

Fig. 6. Decrease in frequency of heart rate change.

Analysis of the distirbution of infants who exhibited decreases and increases in the frequency of heart rate change to the cutaneous stimuli from the first to the second trial block indicated that although a greater number of Ss manifested a decrease than manifested an increase, this difference was not statistically significant (Table 12).

Table 12. Distribution of Ss exhibiting a decrease, an increase and no change in frequency of heart rate change from the first trial block (Cutaneous Stimuli)

	Number of Ss showing			
Trial block	Decrease	Increase	p*	No change
2	11	6	NS	3

*One-tailed binomial test

Analysis of these distributions for the auditory stimulus condition yielded results which were more similar to those obtained from the magnitude analyses than was the case for the cutaneous stimulus condition. In none of the trial blocks was a significant difference obtained between the number of infants exhibiting a decrease and the number exhibiting an increase in the frequency of heart rate change (Table 13).

Table 13. Distributions of Ss exhibiting a decrease, an increase and no change in frequency of heart rate change from the first trial block (Auditory Stimuli)

	Number of Ss showing			
Trial block	Decrease	Increase	p*	No change
2	9	6	NS	5
3	6	7	—	7
4	7	7	NS	6
5	9	6	NS	5
6	9	9	NS	2
7	12	5	NS	3
8	8	6	NS	6

*One-tailed binomial tests

After the criterion for a decrement in the frequency of heart rate changes to the cutaneous stimulus had been reached (i.e. after the second trial block), presentation of the stimulus did not have a consistent effect on the frequency of response. No evidence of a significant decrease in the frequency of response was found in blocks three, four, five or six.

In the last two blocks of trials, however, significant decreases were again manifested (Table 14, Figs. 7 and 8).

Table 14. Frequency of heart rate change after criterion for response decrement had been reached (Cutaneous Stimuli)

Trial block	$\bar{X}$ no. of heart rate changes	s.d.	$\bar{X}$ amount of decrease from first trial block	T*	n	p**
3	3.44	1.22	.39	33.5	15	NS
4	3.48	1.25	.35	31.0	13	NS
5	3.46	1.09	.37	34.0	14	NS
6	3.40	1.31	.43	25.0	12	NS
7	3.19	1.39	.64	29.0	15	.04
8	3.20	1.10	.63	30.0	15	.04

*Wilcoxon matched-pairs signed-ranks tests

**One-tailed tests

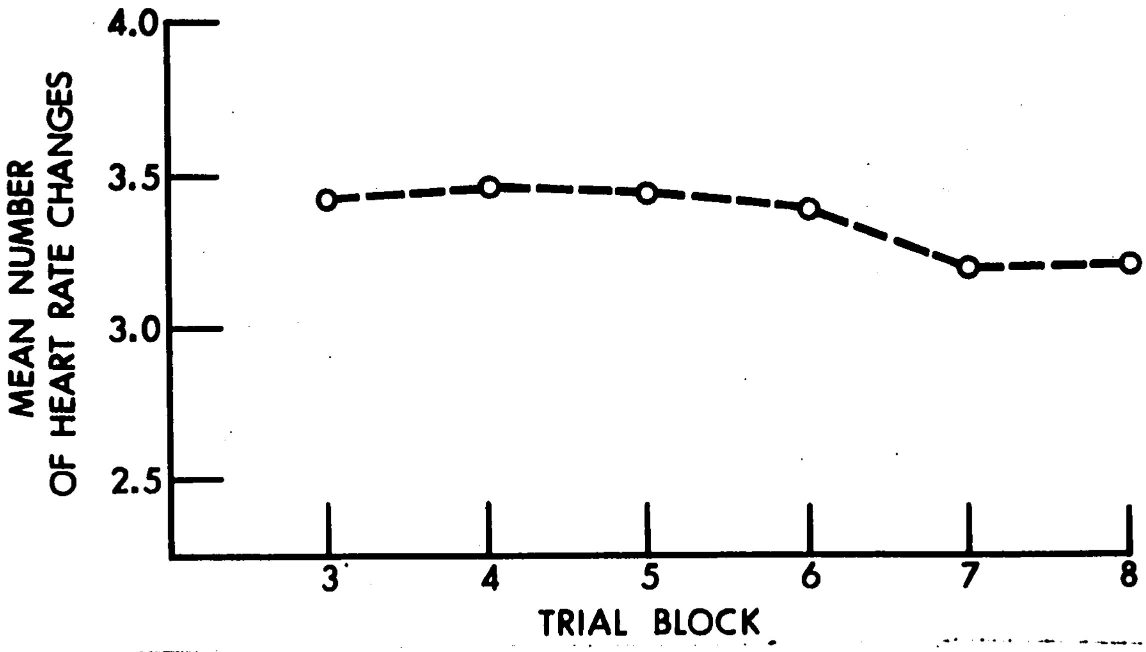

Fig. 7. Frequency of heart rate change after criterion for response decrement had been reached. (Cutaneous Stimuli)

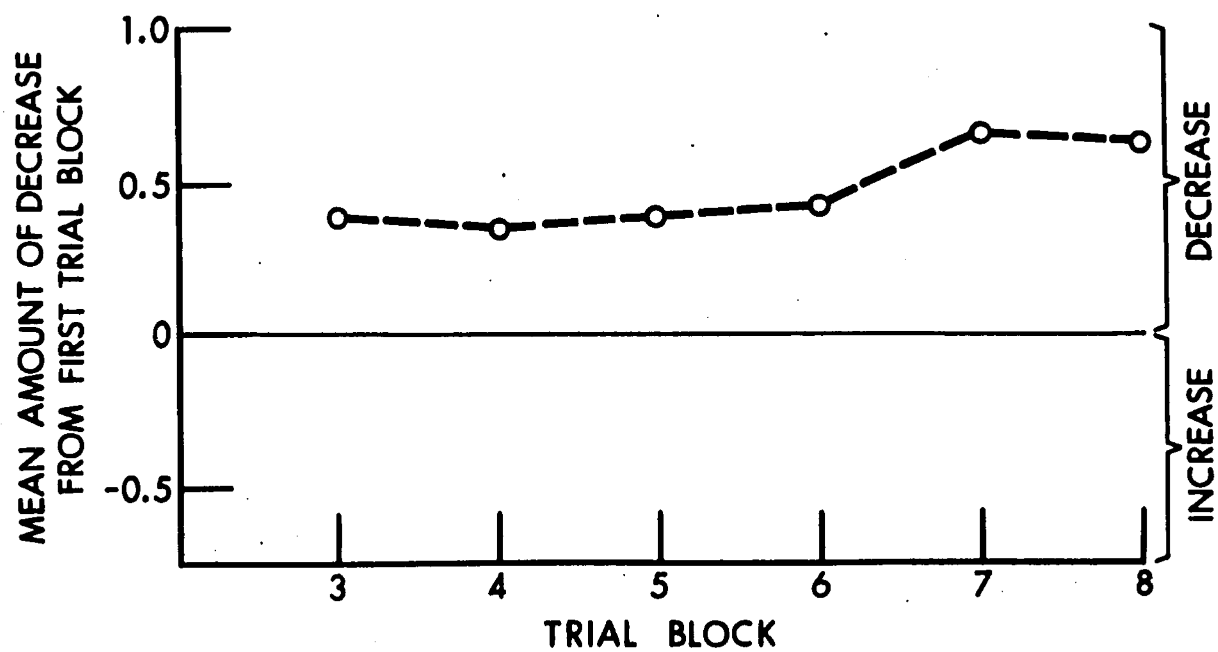

Fig. 8. Decrease in frequency of heart rate change after criterion for response decrement had been reached (Cutaneous Stimuli)

Analysis of the difference between the number of Ss who exhibited decreases and the number who exhibited increases in the frequency of heart rate change to the cutaneous stimuli after the criterion for response decrement had been reached yielded results which were consistent with those obtained from the magnitude analyses. In the third, fourth, fifth and sixth blocks of trials, no significant differences were found between the number of infants manifesting a decrease and the number manifesting an increase in the frequency of response (Table 15). In each of the

Table 15. Distribution of Ss exhibiting a decrease, an increase and no change in frequency of heart rate change after the criterion for response decrement had been reached

(Cutaneous Stimuli)

	Number of Ss showing			
Trial block	Decrease	Increase	p*	No change
3	9	6	NS	5
4	7	6	NS	7
5	10	5	NS	5
6	8	4	NS	8
7	11	4	.06	5
8	11	4	.06	5

*One-tailed binomial tests

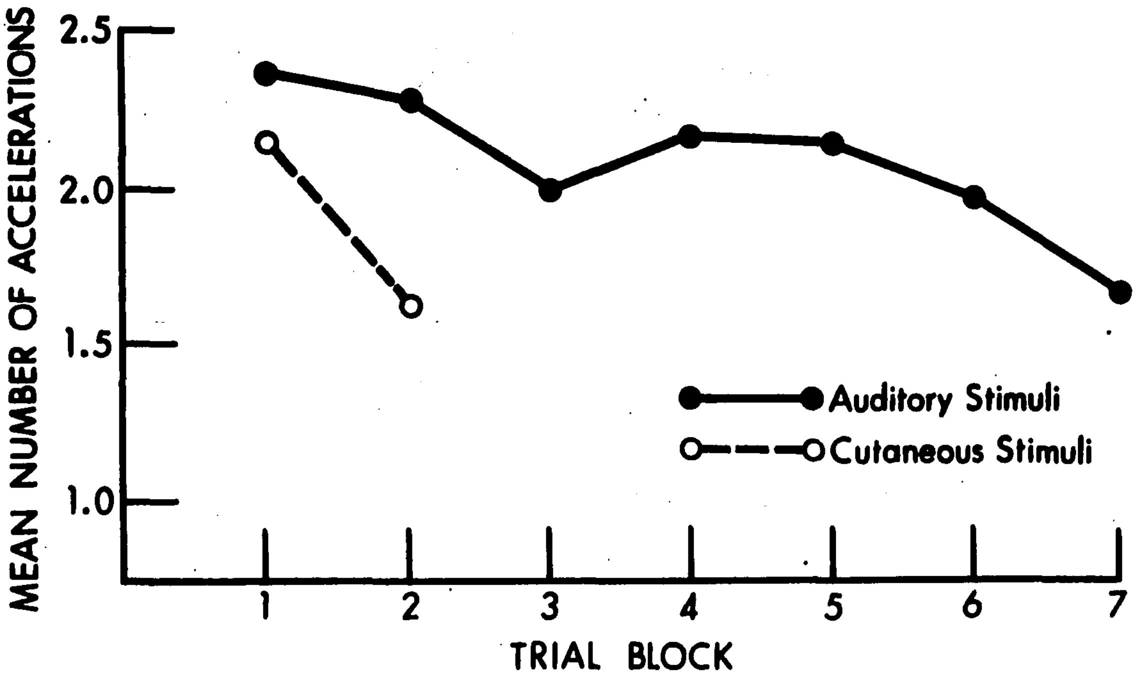

Fig. 9. Frequency of heart rate acceleration.

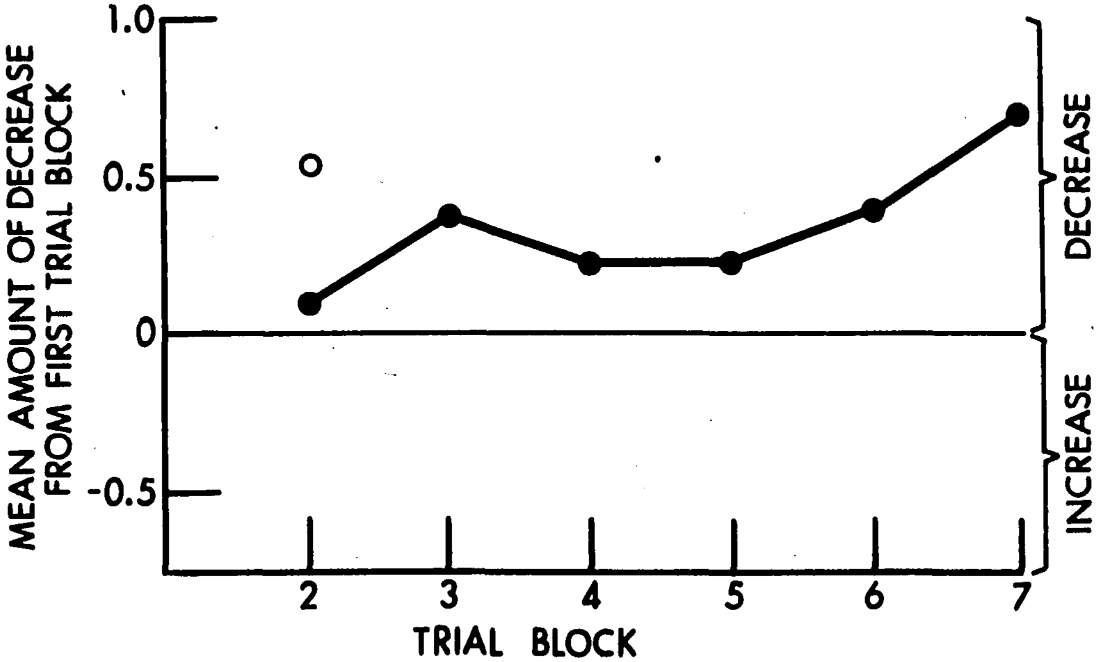

Fig. 10. Decrease in frequency of heart rate acceleration.

in a significant decrease in the frequency with which heart rate accelerations occurred until the seventh block of trials (Table 17, Figs. 9 and 10).

Table 17. Frequency of heart rate acceleration (Auditory Stimuli)

Trial block	$\bar{X}$ no. of heart rate accelerations	s.d.	$\bar{X}$ amount of decrease from first trial block	T*	n	p**
1	2.38	1.35	—			
2	2.28	1.52	.10	46.5	14	NS
3	2.00	.98	.38	52.0	17	NS
4	2.17	1.09	.21	61.0	16	NS
5	2.16	1.11	.22	32.0	12	NS
6	1.99	1.19	.39	54.5	16	NS
7	1.68	1.17	.70	48.5	19	.03

*Wilcoxon matched-pairs signed-ranks tests

**One-tailed tests

Analysis of the distributions of infants who exhibited decreases and increases in the frequency of cardiac accelerations yielded results which were in the same direction as those obtained from the magnitude analyses. The number of infants who exhibited a decrease in the frequency of accelerations to the cutaneous stimuli from the first to the second trial block was greater than the number who exhibited an increase although this difference was not statistically significant (Table 18). For the auditory stimuli the difference between the number of Ss who manifested a decrease and the number who manifested an increase in the frequency of accelerations from the first to the seventh trial block,

Table 18. Distribution of Ss exhibiting a decrease, an increase and no change in frequency of heart rate acceleration from the first trial block (Cutaneous Stimuli)

	Number of Ss showing			
Trial block	Decrease	Increase	p*	No change
2	11	5	NS	4

*One-tailed binomial test

although not statistically significant, was also in the expected direction (Table 19).

Table 19. Distribution of Ss exhibiting a decrease, an increase and no change in frequency of heart rate acceleration from the first trial block (Auditory Stimuli)

	Number of Ss showing			
Trial block	Decrease	Increase	p*	No change
2	7	7	NS	6
3	10	7	NS	3
4	8	8	NS	4
5	7	6	NS	7
6	9	7	NS	4
7	13	6	NS	1

*One-tailed binomial tests

The reduction in effectiveness of cutaneous stimulation for the elicitation of cardiac accelerations, initially manifested in the second block of trials, was not consistently maintained in the six subsequent trials blocks. Inspection of Table 20 and of Figures 11 and 12 reveals that although the number of cardiac accelerations made during each of the last six trial blocks was less than that made during the first block, there was a significant decrease only

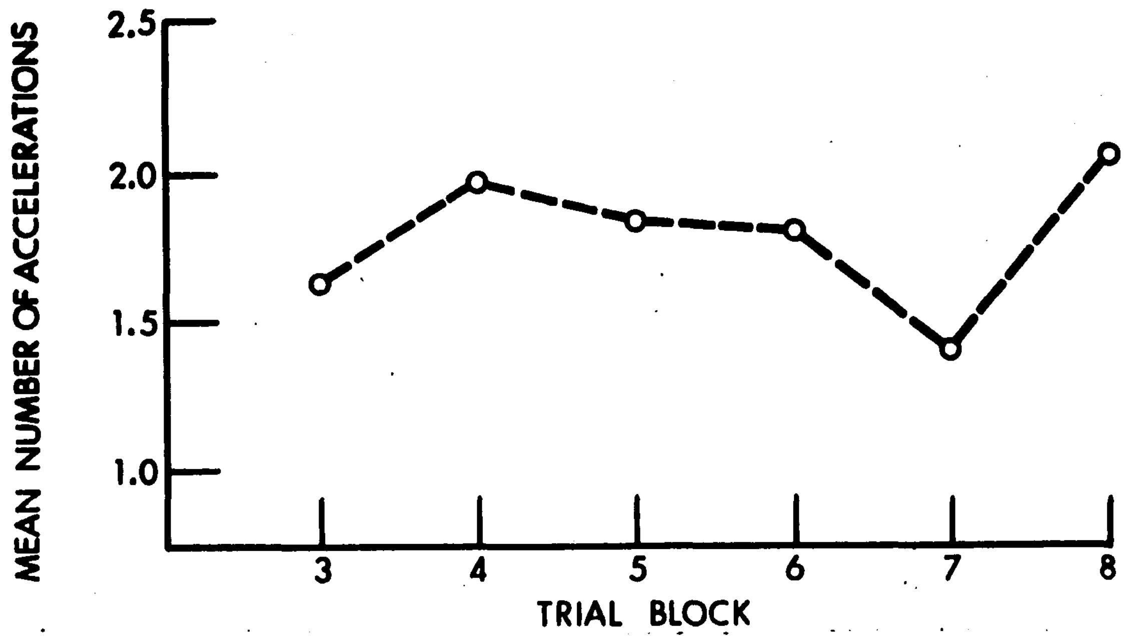

Fig. 11. Frequency of heart rate acceleration after criterion for response decrement had been reached. (Cutaneous Stimuli)

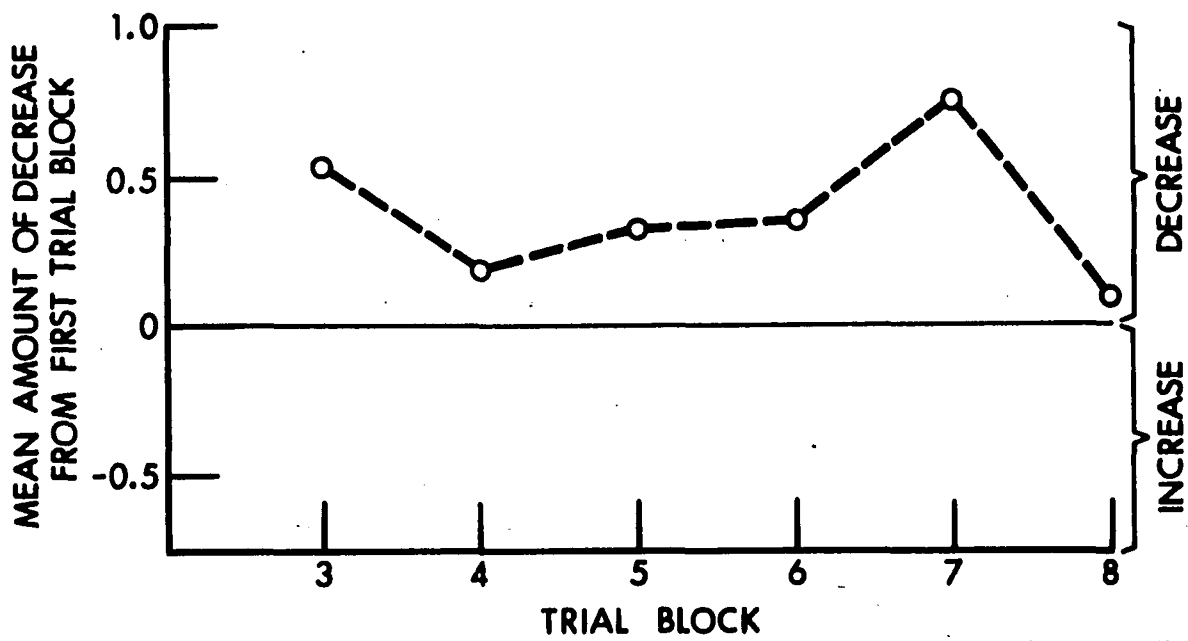

Fig. 12. Decrease in frequency of heart rate acceleration after criterion for response decrement had been reached. (Cutaneous Stimuli)

Table 20. Frequency of heart rate acceleration after criterion for response decrement had been reached (Cutaneous Stimuli)

Trial block	$\overline{X}$ no. of heart rate accelerations	s.d.	$\overline{X}$ amount of decrease from first trial block	T*	n	p**
3	1.62	.96	.53	34.5	16	.04
4	1.98	1.36	.17	58.5	16	NS
5	1.84	1.21	.31	52.0	14	NS
6	1.80	1.15	.35	49.0	16	NS
7	1.40	1.19	.75	11.0	13	<.01
8	2.05	1.00	.10	53.0	15	NS

*Wilcoxon matched-pairs signed-ranks tests

**One-tailed tests

in blocks three and seven. The difference between the number of Ss manifesting a decrease and that manifesting an increase in the frequency of heart rate acceleration from the first to each of the last six trial blocks was also significant only for the third and seventh blocks (Table 21).

Table 21. Distribution of Ss exhibiting a decrease, an increase and no change in frequency of heart rate acceleration after criterion for response decrement had been reached (Cutaneous Stimuli)

	Number of Ss showing			
Trial block	Decrease	Increase	p*	No change
3	12	4	.04	4
4	8	8	NS	4
5	9	4	NS	7
6	9	7	NS	4
7	11	2	.01	7
8	7	8	–	5

*One-tailed binomial tests

Repeated presentation of the auditory stimulus after the trial block in which a reduction in the frequency of cardiac accelerations first occurred (i.e. after the seventh trial block) resulted in an apparent recovery of response. In the eighth trial block, neither the decrease in the frequency of acceleration (Table 22) nor the proportion of infants who exhibited a decrease (Table 23) was statistically significant.

Table 22. Frequency of heart rate acceleration after criterion for response decrement had been reached (Auditory Stimuli)

Trial block	$\overline{X}$ no. of heart rate accelerations	s.d.	$\overline{X}$ amount of decrease from first trial block	T*	n	p**
8	2.36	1.02	.02	52.5	14	NS

*Wilcoxon matched-pairs signed-ranks test

**One-tailed test

Table 23. Distribution of Ss exhibiting a decrease, an increase and no change in frequency of heart rate acceleration after criterion for response decrement had been reached (Auditory Stimuli)

	Number of Ss showing			
Trial block	Decrease	Increase	p*	No change
8	7	7	NS	6

*One-tailed binomial test

<u>Effect of repeated auditory and cutaneous stimulation on the frequency of heart rate deceleration.</u> As was the case for the

frequency of both cardiac acceleration and cardiac change *per se*, repeated presentation of the cutaneous stimulus was more effective in reducing the frequency of cardiac decelerations than was repeated presentation of the auditory stimulus. As may be seen in Table 24 and in Figures 13 and 14, repeated cutaneous stimulation resulted in a reduction in the frequency of deceleration from the first to 5 of the 7 subsequent trial blocks with a significant reduction occurring by the last block of trials (Table 24).

Table 24. Frequency of heart rate deceleration (Cutaneous Stimuli)

Trial block	$\bar{X}$ no. of heart rate decelerations	s.d.	$\bar{X}$ amount of decrease from first trial block	T*	n	p**
1	1.68	.92	—			
2	1.55	1.21	.13	76.0	18	NS
3	1.82	1.25	-.14[1]			
4	1.50	1.15	.18	47.5	15	NS
5	1.62	1.16	.06	70.0	17	NS
6	1.60	.88	.08	79.0	18	NS
7	1.79	1.18	-.11[1]			
8	1.15	.81	.53	15.0	13	<.025

*Wilcoxon matched-pairs signed-ranks tests

**One-tailed tests

[1] A negative value indicates an increase.

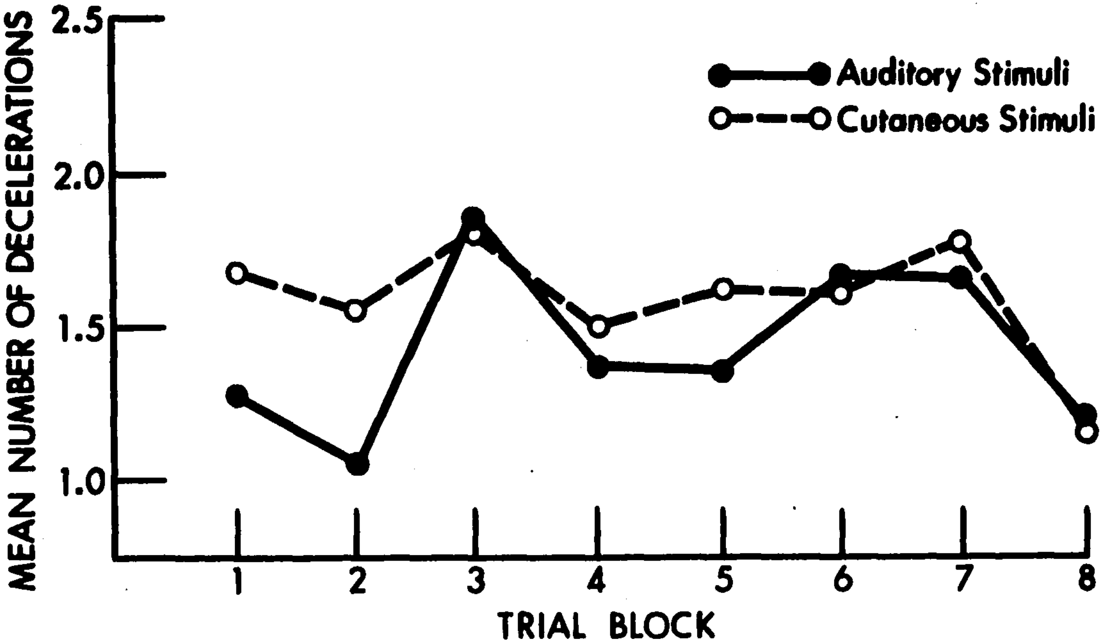

Fig. 13. Frequency of heart rate deceleration.

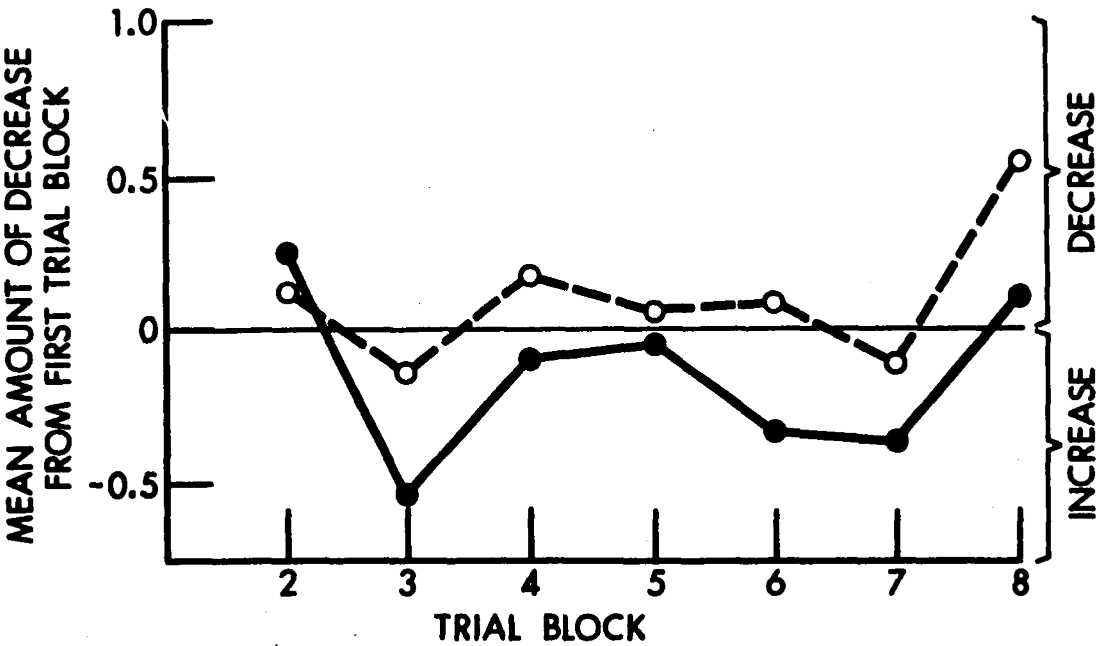

Fig. 14. Decrease in frequency of heart rate deceleration.

In contrast to the reduction in effectiveness of cutaneous stimulation for the elicitation of cardiac deceleration, repeated auditory stimulation did not result in a systematic decrease in the frequency of cardiac deceleration. In none of the trial blocks was there a significant reduction in the frequency of heart rate deceleration (Table 25, Figs. 13 and 14). Moreover, in 5 of the 7 trial blocks, an increase (non-significant) was manifested.

Table 25. Frequency of heart rate deceleration (Auditory Stimuli)

Trial block	$\overline{X}$ no. of heart rate decelerations	s.d.	$\overline{X}$ amount of decrease from first trial block	T*	n	p**
1	1.28	.96	—			
2	1.04	1.16	.24	35.5	14	NS
3	1.84	.90	- .56[1]			
4	1.38	.92	- .10[1]			
5	1.34	.83	- .06[1]			
6	1.64	1.06	- .36[1]			
7	1.66	1.11	- .38[1]			
8	1.18	.91	.10	66.0	17	NS

*Wilcoxon matched-pairs signed-ranks tests

**One-tailed tests

[1] A negative value indicates an increase.

Analysis of the distributionsof infants exhibiting decreases and increases in the frequency of heart rate deceleration yielded results which paralleled those obtained from the magnitude analyses. Of the infants administered the cutaneous stimulus, the number who manifested a decrease in the frequency of cardiac deceleration in the eighth block of trials was significantly greater than the number who manifested an increase (Table 26). For the auditory stimulus,

Table 26. Distribution of Ss exhibiting a decrease, an increase and no change in frequency of heart rate deceleration from the first trial block (Cutaneous Stimuli)

	Number of Ss showing			
Trial block	Decrease	Increase	p*	No change
2	9	9	NS	2
3	4	7	—	9
4	9	6	NS	5
5	8	9	—	3
6	10	8	NS	2
7	7	6	NS	7
8	10	3	.05	7

*One-tailed binomial tests

on the other hand, there was no evidence of a difference between the number of Ss showing a decrease and the number showing an increase in the frequency of heart rate deceleration from the first to any of the subsequent trial blocks (Table 27).

Table 27. Distribution of Ss exhibiting a decrease, an increase and no change in frequency of heart rate deceleration from the first trial block (Auditory Stimuli)

	Number of Ss showing			
Trial block	Decrease	Increase	p*	No change
2	9	4	NS	7
3	5	12	—	3
4	6	8	—	6
5	7	6	NS	7
6	4	10	—	6
7	8	12	—	0
8	9	8	NS	3

*One-tailed binomial tests

<u>Relationship between ipsilateral conjugate eye movement and heart rate acceleration and deceleration.</u> Inasmuch as repeated stimulation had opposite effects on eye movement and cardiac responses,

it was possible that these two behaviors were negatively correlated. To ascertain the relationship between the eye movement response and the cardiac response, the data from the two measures were examined simultaneously. This was done by sorting the infants into two groups according to whether they were "consistent" or "inconsistent" in their responses. Those classified as "consistent" exhibited either:

1) a decrease in the frequency of ipsilateral eye movement AND an decrease in the frequency of heart rate acceleration, or

2) a decrease in the frequency of ipsilateral eye movement AND a decrease in the frequency of heart rate deceleration.

Those infants classified as "inconsistent" exhibited either:

1) a decrease in the frequency of ipsilateral eye movement but NO decrease in the frequency of either heart rate acceleration or deceleration, or

2) a decrease in the frequency of either heart rate acceleration or deceleration but NO decrease in the frequency of ipsilateral eye movement. All of the infants were classified in this manner for each of the seven blocks of trials.

The distributions of "consistent" and "inconsistent" infants are presented in Tables 28-31. To the auditory stimulus presentations, the number of "consistent" Ss did not differ significantly from the number of "inconsistent" Ss in any trial block except

Table 28. Distribution of "consistent" and "inconsistent" Ss in each trial block: Ipsilateral conjugate eye movement and heart rate acceleration (Auditory Stimuli)

Number of Ss who were	Trial Block 2	3	4	5	6	7	8
"Consistent"	6	8	15	11	9	12	11
"Inconsistent"	14	12	5	9	11	8	9
p*	NS	NS	.04	NS	NS	NS	NS

*Two-tailed binomial tests

Table 29. Distribution of "consistent" and "inconsistent" Ss in each trial block: Ipsilateral conjugate eye movement and heart rate deceleration (Auditory Stimuli)

Number of Ss who were	Trial Block 2	3	4	5	6	7	8
"Consistent"	10	9	11	7	10	7	7
"Inconsistent"	10	11	9	13	10	13	13
p*	NS	NS	NS	NS	NS	NS	NS

*Two-tailed binomial tests

Table 30. Distribution of "consistent" and "inconsistent" Ss in each trial block: Ipsilateral conjugate eye movement and heart rate acceleration (Cutaneous Stimuli)

Number of Ss who were	Trial Block 2	3	4	5	6	7	8
"Consistent"	13	8	10	11	12	10	14
"Inconsistent"	7	12	10	9	8	10	6
p*	NS	NS	NS	NS	NS	NS	NS

*Two-tailed binomial tests

Table 31. Distribution of "consistent" and "inconsistent" Ss in each trial block: Ipsilateral conjugate eye movement and heart rate deceleration (Cutaneous Stimuli)

Number of Ss who were	Trial Block 2	3	4	5	6	7	8
"Consistent"	11	12	11	10	7	10	9
"Inconsistent"	9	8	9	10	13	10	11
p*	NS	NS	NS	NS	NS	NS	NS

*Two-tailed binomial tests

of heart rate acceleration from the first trial block, and
2) amount of decrease in the frequency of ipsilateral eye movement from the first trial block and amount of decrease in the frequency of heart rate deceleration from the first trial block.
The rho values obtained ranged from - .10 to + .33; none were statistically significant (two-tailed tests).

Summary of results

Repeated presentation of initially equivalent auditory and cutaneous stimuli yielded the following main findings:
1) By the third block of auditory stimulus presentations (trials 11-15), there was a significant decrease in the frequency of ipsilateral conjugate eye movement responses and a significantly greater number of infants who exhibited a decrease than exhibited an increase in the frequency of such responses. Under conditions of repeated cutaneous stimulation, on the other hand, there was no evidence of either a decrease in the frequency of ipsilateral conjugate eye movement responses or a difference between the number of infants who exhibited a decrease and the number who exhibited an increase in the frequency of response from the first to any of the subsequent trial blocks.
2) Analysis of the data derived from the heart rate measure yielded results which were opposite to those obtained for the

eye movement response. Under conditions of repeated cutaneous stimulation, there was a significant decrease in the frequency of both heart rate change and heart rate acceleration by the second block of trials (trials 6-10), a significant decrease in the frequency of heart rate deceleration by the eighth block of trials (trials 36-40) and a significantly greater number of infants who exhibited a decrease than exhibited an increase in the frequency of deceleration from the first to the eighth block of trials. In contrast, the only evidence of an effect of repeated auditory stimulation on heart rate was provided by the finding of a significant decrease in the frequency of cardiac acceleration in the seventh block of trials (trials 31-35).

3) There was no evidence of a relationship between the amount of decrease in the frequency of ipsilateral eye movement responses and the amount of decrease in the frequency of either heart rate acceleration or heart rate deceleration to either the auditory or the cutaneous stimuli.

CHAPTER V

DISCUSSION

The results of the present investigation provide some evidence of differences between sensory modalities in the durability of effectiveness of repeated presentations of initially equivalent stimuli for both somatic and autonomic responsiveness in the human neonate. A laterally presented auditory stimulus which is initially effective for the elicitation of conjugate eye movements in the direction of the stimulus becomes less effective for the elicitation of this response when it is repeatedly presented. This reduction in effectiveness is manifested by a significant decrease in the frequency of such eye movement responses. The frequency of conjugate eye movements in the direction of a laterally presented cutaneous stimulus which is of equivalent initial effectiveness to the auditory stimulus, on the other hand, is not significantly reduced as a consequence of repeated stimulus presentation.

The finding of a more rapid reduction in the effectiveness of the auditory than of the cutaneous stimulus for the elicitation of ipsilateral eye movement responses supports the hypothesis that, for the human newborn, cutaneous stimulation is more resistant to response decrement than is auditory stimulation. The obtained direction of difference in rate of habituation of ipsilateral eye movement responsiveness to the two stimuli is consistent with the hypothesis that during the neonatal period, cutaneous input is more effective for the persistent elicitation of directional orienting responses than is auditory input. This hierarchical dominance of cutaneous over auditory input during this period suggests a possible ontogenetic primacy of proximal sources of stimulation for the maintenance of somatic responsiveness. The present results are therefore consistent with the hypothesized hierarchical relationship among afferent systems according to which proximoreceptive sources of stimulation predominate over teloreceptive sources of stimulation in determining the directional orienting behaviors of the young organism (Birch, 1962; Maier and Schneirla, 1935; Schneirla, 1965).

The suggested dominance of proximal over distal stimulus inputs for the persistence of somatic responsiveness in early life is significant for an understanding of behavioral organization in the newborn infant as well as for an understanding of developmental changes in behavioral organization. The greater durability of effectiveness of proximal inputs during early postnatal life would provide for a greater and more continual effective availability of such inputs and would thereby enhance the opportunity for the infant's behavior to become organized and integrated around somesthetic sources of stimulation. Such a hierarchical relationship could therefore result in the establishment and elaboration of different patterns of behavior than would be the case if teloreceptive sensory inputs predominated over proximoreceptive inputs during the neonatal period. Hence, the early establishment of proximal input prepotency for the persistent elicitation of directed somatic responses might have far-reaching consequences for behavioral development.

Analysis of the comparative durability of effectiveness of initially equivalent auditory and cutaneous stimuli for autonomic rather than somatic responsiveness also revealed a difference between modalities although the <u>direction</u> of the difference was opposite to and independent of that obtained for the somatic response measure. The rate of response decrement of cardiac responsiveness to repeated presentations of the cutaneous stimulus was more rapid than to repeated presentations of the auditory stimulus. This difference between modalities was manifested by a significant reduction in the frequency of heart rate changes, heart rate accelerations and heart rate decelerations to repeated cutaneous stimulation but not to repeated auditory stimulation. These findings are suggestive of a greater durability of effectiveness of auditory than of cutaneous input for autonomic responsiveness in the newborn infant.

In view of the finding of opposite and independent effects of repeated stimulation on somatic and autonomic responsiveness, interpretation of the results in terms of the originally hypothesized hierarchical ordering of afferent systems in the neonate is clearly unwarranted. Although the results derived from the somatic response measure, when considered alone, provide evidence in support of the hypothesis, those derived from the autonomic measure do not. This suggests that the relationships between and among sensory systems in maintaining neonatal responsiveness are more complex than is implied in the simple postulation of a unitary proximoreceptor system dominance. Perhaps the hypothesized hierarchy is only pertinent to an understanding of directed orienting behaviors which are specific, discrete and localized and does not account for the more generalized, less differentiated responses of the newborn. In any case, the simple hypothesis cannot be maintained in its original form but must be modified in accordance with a consideration of the type of response system being studied.

A possible modification of the original hypothesis is that there is more than one hierarchical ordering of afferent systems in the neonate and that different types of sensory systems are hierarchically predominant for different types of behavior. Thus, proximoreceptive inputs may predominate over teloreceptive inputs in determining directed somatic behaviors whereas distal sources of stimulation may predominate over proximal sources of stimulation insofar as generalized, autonomic behavior is concerned. Exploration of this hypothesis requires investigation of the relationships between the effects of various proximal and distal stimuli on different somatic and autonomic responses.

Interpretation of the data typically derived from both classical conditioning and habituation studies enables an alternative modification of the original hypothesis. It has consistently been demonstrated (Dykeman, Gantt and Whitehorn, 1956) that during the early stages of conditioning, there is a widespread and persistent autonomic effect of UCS and CS pairing which gradually diminishes and eventually disappears with the emergence and establishment of a stable somatic CR. A shift from the preponderance of autonomic reactions (e.g. cardiac and respiratory changes) to the preponderance of directed somatic responses (e.g. head turning, eye movements) also occurs in the course of repeated presentation of a single stimulus (Sokolov, 1958). The persistence of autonomic reactivity during the first stages of the establishment of a discrete somatic response and the subsequent diminution and disappearance of autonomic reactivity indicates that autonomic responses are an earlier, more generalized mode of reaction to stimulation and that these non-differentiated generalized reactions become functionally less integrated in the final directed act to the extent that discrete somatic responses emerge.

If the abovedescribed line of analysis is placed within a developmental framework, it can be hypothesized that generalized autonomic responsiveness precedes discrete somatic responsiveness in behavioral ontogenesis as it does in the course of the establishment of a given directed response. Interpretation of the findings of the present experiment in relation to the hypothesized sequence of development would suggest that for the neonate, the effectiveness of cutaneous input has reached the stage wherein generalized responsiveness to such stimulation has been reduced because stable somatic reactions have already become established. The effectiveness of auditory input during the neonatal period, on the other hand, might still be at an earlier stage which is characterized by more generalized reactivity. Thus, the hierarchical predominance of auditory over cutaneous stimulation for the persistent elicitation of cardiac responses and the hierarchical predominance of cutaneous over auditory stimulation for the persistent elicitation of somatic responses may be understood in terms of differences between the levels of organization of the two modalities during the neonatal period such that auditory input still tends to have a widespread generalized effect whereas cutaneous input has come to effect directed somatic reactions. If this line of interpretation is valid, then one would expect that the effects of repeated auditory stimulation obtained during the neonatal period would obtain for repeated cutaneous stimulation during an earlier stage of development and that the effects of repeated cutaneous stimulation obtained during the neonatal period would obtain for repeated auditory stimulation during a later stage of development. Confirmation or rejection of these predictions is, of course, dependent upon systematic study of the durability of effectiveness of different types of afferent inputs for various somatic and autonomic responses at different stages of ontogenesis.

In addition to its relevance for an understanding of sensory-system hierarchy and its behavioral consequences, the finding of opposite and apparently independent effects of repeated stimulation on somatic and autonomic responsiveness in the neonate has implications for an understanding of the phenomena of habituation *per se*. Since repeated stimulation can and does result in a decrease in the frequency of one type of response and has no effect on the frequency of another type of response, it would appear that habituation, rather than being a simple unitary phenomenon which indiscriminately comprises any and all response systems, is specific to the *type* of motor outflow. The specificity of habituation suggests that different mechanisms underlie the decrease in frequency of different types of response and thereby calls into question the utility of the concept of generalized organismic habituation and the broader concept of generalized organismic arousal, so frequently referred to in contemporary neurophysiology and physiological psychology (Magoun, 1963; Pribram, 1963; Sharpless, 1964; Sokolov, 1960).

Application of the concept of generalized organismic arousal to the analysis of behavioral organization in the human newborn has led to the assertion that somatic responsiveness parallels and is functionally equivalent to autonomic responsiveness (Bridger, 1961; Bridger, Birns and Blank, 1965; Bridger and Reiser, 1959). This assertion is based upon the finding of a positive correlation between cardiac activity and generalized somatic activity in the young infant. However, since this generalized somatic activity derives from a behavioral rating scale of overall responsiveness (including crying, limb movements and head movements) and since the results of the present experiment reveal that autonomic reactivity is neither parallel nor equivalent to discrete somatic reactivity, it would seem that autonomic responsiveness is related to generalized bodily activity but not to discrete directional responses.

Evaluation of the concept of generalized behavioral arousal in relation to the analysis of directed orienting behavior also leads to a reconsideration of the validity of the neo-Pavlovian concept of orientation. Several contemporary Soviet workers (e.g. Anokhin, 1958; Asafov, 1958; Biriukov, 1958; Sokolov, 1958, 1960) have described the initial reaction of various organisms to the presentation of different kinds of "novel" stimuli in terms of an orienting reflex (OR). This OR is defined as a "nonspecific, generalized reaction of activation of the organism that includes motor, vascular, respiratory and bioelectrical components" (Sokolov, 1958, p. 222). The OR is therefore considered to be a unitary holistic response having somatic (e.g. turning of the head and eyes in the direction of the source of stimulation) and vegetative (e.g. cardiac activity, respiration, GSR) components. According to the Soviet workers, the individual components are not separate independent reflexes but are manifestations of a central integration (Anokhin, 1958). The strength of the OR can therefore be measured via any of the individual components.

Sokolov and his co-workers (Sokolov, 1958; Voronin and Sokolov, 1960) have maintained that when a stimulus is repeatedly presented, ALL components of the OR become extinguished (i.e. habituated). However, the comparative analysis of the effects of repeated stimulation on the various efferent components of the OR in the present experiment as well as in the experiments of several Soviet researchers has revealed a non-parallel rate of habituation of the different types of response as well as species - and age-specific differences in habituation rate. In pigeons, for example, somatic responsiveness to repeated auditory stimulation disappears more rapidly than autonomic responsiveness whereas in rabbits, the reverse order of disappearance of response characterizes the effect of repeated auditory stimulation (Zagorulko and Sollertinskaia, 1958). In puppies, infant monkeys and 1-3 month old premature infants, the motor and autonomic components of the OR are extinguished independently and at different ages (Nikitina and Novikova, 1958; Polikanina and Probatova, 1958). Even within the autonomic system, the rates of habituation of different responses are not parallel so that in both dogs and rabbits, a reduction in cardiac reactivity precedes a reduction in respiratory reactivity

(Petelina, 1958; Zagorulko and Sollertinskaia, 1958).

These findings, when considered in conjunction with the results of the present experiment, make it difficult to sustain the concept of an OR as a total organismic response. The various autonomic and somatic components may more appropriately be viewed as representative of qualitatively different classes of behavior having different underlying mechanisms. It would appear that autonomic reactions are representative of generalized, undifferentiated and non-directed behaviors whose primary function is that of organismic arousal. As such, these generalized responses are probably related to the affective and emotional state of the organism. Directed orienting reactions, on the other hand, represent discrete somatic behaviors which occur in relation to the source of stimulation and which serve to orient and guide the organism. As such, directionalized behaviors would seem to be especially important in the development of perceptual and other cognitive functions.

CHAPTER VI

SUMMARY

To determine the comparative effectiveness of auditory and cutaneous stimulation for the persistence of responsiveness in the human neonate, the effects of repeated presentations of initially equivalent auditory and cutaneous stimuli were compared. Two types of response were studied. One was a somatic and the other an autonomic response. The somatic response indicator was lateral conjugate eye movement in the direction of the stimulus and the autonomic response indicator was heart rate change.

Forty healthy newborn infants, ranging in age from 24 to 71 hours, served as subjects. Twenty of the Ss were administered 40 successive presentations of a 90 db white noise. The remaining 20 Ss were touched on 40 successive trials with a No. 12 round camel's hair brush. The duration of each stimulus was one second and the interstimulus interval was eight seconds.

Repeated presentation of the initially equivalent auditory and cutaneous stimuli yielded the following results:

1) By the third block of auditory stimulus presentations (Trials 11-15), there was a significant decrease in the frequency of ipsilateral conjugate eye movement responses and a significantly greater number of infants who exhibited a decrease than exhibited an increase in

the frequency of such eye movement responses. On the other hand, at no time during the course of repeated cutaneous stimulation was there any evidence of either a decrease in the frequency of ipsilateral conjugate eye movement responses or a difference between the number of infants who manifested a decrease and the number who manifested an increase in the frequency of response.

2) By the second block of cutaneous stimulus presentations (trials 6-10), there was a significant decrease in the frequency of both heart rate changes and heart rate accelerations. By the eighth block of cutaneous stimulus presentations (trials 36-40), there was a significant decrease in the frequency of heart rate decelerations and a significantly greater number of infants who exhibited a decrease than exhibited an increase in the frequency of cardiac decelerations. In contrast, the only evidence of a reduction in the effectiveness of auditory stimulation was provided by the finding of a significant decrease in the frequency of cardiac accelerations by the seventh block of trials (trials 31-35).

3) There was no evidence of a relationship between the amount of decrease in the frequency of ipsilateral eye movement responses and the amount of decrease in the frequency of either cardiac accelerations or cardiac decelerations to either the auditory or the cutaneous stimuli.

These results suggest that, for the human newborn, cutaneous input is prepotent over auditory input for the persistence of directed somatic responsiveness and that auditory input is prepotent over cutaneous input for the persistence of autonomic responsiveness. The findings therefore support the general hypothesis of a hierarchical relationship among afferent systems in the young organism. They also support the more specific hypothesis of the ontogenetic primacy of proximoreceptive sources of stimulation in controlling directed orienting behavior. Although the finding of opposite and independent effects of repeated stimulation on somatic and autonomic responsiveness indicates that the simple hypothesis of proximal input prepotency does not adequately account forthe behavior of the human newborn, the results are consistent with a modified version of the initial hypothesis.

The findings were also discussed in relation to the concepts of generalized organismic arousal and habituation as well as the concept of a unitary orienting reflex.

BIBLIOGRAPHY

Anokhin, P.K. The role of the orienting-exploratory reaction in the formation of the conditioned reflex. In L.G. Voronin, A.N. Leontiev, A.R. Luria, E.N. Sokolov, & O.S. Vinogradova (Eds.), Orienting reflex and exploratory behavior. Moscow, Acad. Ped. Sci. RSFSR, 1958. Pp. 141-152.

Apgar, V., Holoday, D.A., James, L.S., Weisbrot, I.M., & Berrien, C. Evaluation of the newborn infant: second report. J.A.M.A., 1958, 168, 1985-1988.

Asafov, B.D. Change in the dynamics of autonomic components of the OR with employment of sound stimuli of progressively increasing intensity. In L.G. Voronin, A.N. Leontiev, A.R. Luria, E.N. Sokolov, & O.S. Vinogradova (Eds.), Orienting reflex and exploratory behavior. Moscow, Acad. Ped. Sci. RSFSR, 1958. Pp. 155-162.

Bartoshuk, A.K. Electromyographic reactions to strong auditory stimulation as a function of alpha amplitude. J. comp. physiol. Psychol., 1959, 52, 540-545.

Bartoshuk, A.K. Human neonatal cardiac acceleration to sound: habituation and dishabituation. Perc. mot. skills, 1962, 15, 15-27. (a)

Bartoshuk, A.K. Response decrement with repeated elicitation of human neonatal cardiac acceleration to sound. J. comp. physiol. Psychol., 1962, 55, 9-13. (b)

Bartoshuk, A.K. Human neonatal cardiac responses to sound: a power function. Psychon. Sci., 1964, 1, 151-152.

Birch, H.G. Comparative psychology. In F. Marcuse (Ed.), Areas of psychology. New York: Harper, 1954. Pp. 446-477.

Birch, H.G. Dyslexia and the maturation of visual function. In J. Money (Ed.), Reading disability. Baltimore, Md.: Johns Hopkins Press, 1962. Pp. 161-169.

Biriukov, D.A. On the nature of the orienting reaction. In L.G. Voronin, A.N. Leontiev, A.R. Luria, E.N. Sokolov, & O.S. Vinogradova (Eds.), Orienting reflex and exploratory behavior. Moscow, Acad. Ped. Sci. RSFSR, 1958. Pp. 17-24.

Brackbill, Y. Research and clinical work with children. In R. A. Bauer (Ed.), Some views on Soviet psychology. Wash. D.C.: Amer. Psychol. Assoc., 1962.

Bridger, W.H. Sensory habituation and discrimination in the human neonate. Amer. J. Psychiat., 1961, 117, 991-996.

Bridger, W.H. Sensory discrimination and autonomic function in the newborn. J. Amer. Acad. Child Psychiat., 1962, 1, 67-82.

Bridger, W.H., Birns, B.M., & Blank, M.A. Comparison of behavioral ratings and heart rate measurements in human neonates. Psychosomat. Med., 1965, 27 (2), 123-133.

Bridger, W.H. & Reiser, M.F. Psychophysiologic studies of the neonate: an approach toward the methodological and theoretical problems involved. Psychosomat. Med., 1959, 21 (4), 265-276.

Bronshtein, A.I., Antonova, T.G., Kamenetskaya, A.G., Luppova, N.M., & Systova, V.A. On the development of the functions of analyzers in infants and some animals at the early stages of ontogenesis. In Problems of evolution of physiologic functions. Moscow: Acad. Sci. USSR, 1958. Pp. 106-117.

Coghill, G.E. Anatomy and the problem of behavior. London: Cambridge Univ. Press, 1929.

Davis, C.M., Crowell, D.H., & Chun, B.J. Monophasic heart rate accelerations in human infants to peripheral stimulation. Paper presented at APA meeting. Chicago, Ill., Sept. 1965.

Disher, D.R. The reactions of newborn infants to chemical stimuli administered nasally. In F.C. Dockeray (Ed.), Studies of infant behavior. Columbus, Ohio: Ohio State Univ. Press, 1934, No. 12, Pp. 1-52.

Dykman, R.A., Gantt, W.H., & Whitehorn, J.C. Conditioning and emotional sensitization and differentiation. Psychol. Monogr., 1956, 70 (15), 1-17.

Engen, T. & Lipsitt, L.P. Decrement and recovery of responses to olfactory stimuli in the human neonate. J. comp. physiol. Psychol. 1965, 59, 312-316.

Engen, T., Lipsitt, L.P., & Kaye, H. Olfactory responses and adaptation in the human neonate. J. comp. physiol. Psychol., 1963, 56 (1), 73-77.

Forbes, H.S., & Forbes, H.B. Fetal sense reaction: Hearing. J. comp. Psychol., 1927, 7, 353-355.

Gesell, A., & Amatruda, C.S. The embryology of behavior. New York: Harper, 1945.

Goldfarb, W. Receptor preference in schizophrenic children. Arch. neurol. Psychiat., 1956, 76, 643-652.

Guthrie, E.R. The psychology of learning. (rev. ed.), Gloucester, Mass.: Peter Smith, 1960.

Harris, J.D. Habituatory response decrement in the intact organism. Psychol. Bull., 1943, 40, 385-422.

Hermelin, B., & O'Connor, N. Effects of sensory input and sensory dominance on severely disturbed, autistic children and on subnormal controls. Brit. J. Psychol., 1964, 55, 201-206.

Hickman, R.K. Auditory habituation and discrimination in the human neonate. Unpublished doctoral dissertation, Univ. of Minn., 1963.

Irwin, O.C., & Weiss, L.A. Differential variations in the activity and crying of the newborn infant under different intensities of light: A comparison of observational with polygraph findings. In G.H. Stoddard (Ed.), Studies in infant behavior I. Iowa City, Iowa: Univ. Iowa Stud. Child Welfare, 1934, 9 (4), 139-148.

Jensen, K. Differential reactions to taste and temperature stimuli in newborn infants. Genet. Psychol. Monogr., 1932, 12, 361-479.

Kaye, H., & Levin, G.R. Two attempts to demonstrate tonal suppression of non-nutritive sucking in neonates. Perc. mot. skills, 1963, 17, 521-522.

Koffka, K. The growth of the mind: An introduction to child psychology. New York: Harcourt, Brace & Co., 1928.

Kuo, Z.Y. Ontogeny of embryonic behavior in Aves. IV. The influence of embryonic movements upon the behavior after hatching. J. comp. Psychol., 1932, 14, 109-122.

Leventhal, A.S., & Lipsitt, L.P. Adaptation, pitch discrimination and sound localization in the neonate. Child developm., 1964, 35, 759-767.

Lewin, K. Principles of topological psychology. New York: McGraw-Hill, 1936.

Lipton, E.L., & Steinschneider, A. Studies on the psychophysiology of infancy. Merrill-Palmer Quart., 1964, 10, 103-117.

Magoun, H.W. Central neural inhibition. In M.R. Jones (Ed.), Nebraska symposium on motivation. Lincoln: Univ. Nebraska Press, 1963. Pp. 161-196.

Maier, N.R.F., & Schneirla, T.C. Principles of animal psychology. New York: McGraw-Hill, 1935.

Martin, I. Adaptation. Psychol. Bull., 1964, 61, 35-44.

Nikitina, G.M., & Novikova, E.G. On the characteristics of the manifestation of the orienting reaction in animals during ontogenesis. In L.G. Voronin, A.N. Leontiev, A.R. Luria, E.N. Sokolov, & O.S. Vinogradova (Eds.), Orienting reflex and exploratory behavior. Moscow, Acad. Ped. Sci. RSFSR, 1958. Pp. 314-322.

Peiper, A. Beitraege zur Sinnesphysiologie den Fruehgeburt. Jabhrb. f. Kinderberek, 1924, 104, 195-200.

Peiper, A. Sinnesempfindungen des Kindes vor seiner Geburt. Monatsschr.f. Kinderbk., 1925, 29, 236-241.

Peiper, A. Die Hirntaetigkeit des Saeuglings. Berlin: Julius Springer, 1928.

Petelina, V.V. The autonomic component of the orienting reaction in the vestibular, visual and auditory analyzers. In L.G. Voronin, A.N. Leontiev, A.R. Luria, E.N. Sokolov, & O.S. Vinogradova (Eds.), Orienting reflex and exploratory behavior. Moscow, Acad. Ped. Sci. RSFSR, 1958. Pp. 205-212.

Polikonina, R.I., & Probatova, L.E. On the problem of formation of the orienting reflex in prematurely born children. In L.G. Voronin, A.N. Leontiev, A.R., Luria, E.N. Sokolov, & O.S. Vinogradova (Eds.), Orienting reflex and exploratory behavior. Moscow, Acad. Ped. Sci. RSFSR, 1958. Pp. 330-340.

Pratt, K.C., Nelson, A.K., & Sun, K.H. The behavior of the newborn infant. Columbus, Ohio: Ohio State Univ. Press, 1930, No. 10.

Prechtl, H. The directed head-turning response and allied movements of the human baby. Behaviour, 1958, 13, 212-242.

Pribram, K.H. Reinforcement revisited: A structural view. In M.R. Jones (Ed.), Nebraska symposium on motivation. Lincoln: Univ. Nebraska Press, 1963. Pp. 113-160.

Rosenblatt, J.S., Turkewitz, G., & Schneirla, T.C. Development of suckling and related behavior in neonate kittens. In E. L. Bliss (Ed.), Roots of behavior. New York: Harper, 1962. Pp. 198-211.

Schneirla, T.C. Aspects of stimulation and organization in approach/withdrawal processes underlying vertebrate behavioral development. In D.L. Lehrman, R. Hinde, & E. Shaw (Eds.), Advances in the study of behavior. New York: Acad. Press, 1965. Pp. 2-75.

Sharpless, S.K. Reorganization of function in the nervous system - use and disuse. Ann. rev. Physiol., 1964, 26, 357-388.

Sharpless, S.K. & Jasper, H.H. Habituation of the arousal reaction. Brain, 1956, 79, 655-680.

Sherrington, C.S. The integrative action of the nervous system. New Haven: Yale Univ. Press, 1906.

Sokolov, E.N. The orienting reflex, its structure and mechanisms. In L.G. Voronin, A.N. Leontiev, A.R. Luria, E.N. Sokolov, & O.S. Vinogradova (Eds.), Orienting reflex and exploratory behavior. Moscow, Acad. Ped. Sci. RSFSR, 1958. Pp. 141-152.

Sokolov, E.N. Neuronal models and the orienting influence. In M.A.B. Brazier (Ed.), The central nervous system and behavior III. New York: Josiah Macy Jr. Foundation, 1960.

Stubbs, E.M. The effect of the factors of duration, intensity and pitch of sound stimuli on the responses of newborn infants. In G.H. Stoddard (Ed.), Studies in infant behavior I. Iowa City, Iowa: Univ. Iowa Stud. Child Welfare, 1934, 9 (4), 75-135.

Turkewitz, G. The developmental of spatial orientation in relation to the effective perceptual environment in neonate rats. Unpublished doctoral dissertation, New York Univ., 1966.

Turkewitz, G., Birch, H.G., Moreau, T., Levy, L., & Cornwell, A.C. Effect of intensity of auditory stimulation on directional eye movements in the human neonate. Anim. Behav., 1966, 14, 93-101.

Turkewitz, G., Gordon, E.W., & Birch, H.G. Head-turning in the human neonate: spontaneous patterns. J. genet. Psychol., 1965, 107, 143-158.

Turkewitz, G., Moreau, T., & Birch, H.G. Head position and receptor organization in the human neonate. J. exper. child Psychol., 1966, 4 (2), 169-177.

Turkewitz, G., Moreau, T., & Birch, H.G. Relationship between intensity of cutaneous stimulation and direction of lateral conjugate eye movement in the human neonate. Unpublished manuscript.

Voronin, L.G. & Sokolov, E.N. Cortical mechanisms of the orienting reflex and its relation to the conditioned reflex. In H.H. Jasper & G.D. Smirnov (Eds.), Moscow colloquium on electroencephalography of higher nervous activity. EEG clin. neurophysiol. suppl., 1960, 13, serial E. Pp. 335-346.

Weiss, L.A. Differential variations in the amount of activity of newborn infants under continuous light and sound stimulation. In G.H. Stoddard (Ed.), Studies in infant behavior I. Iowa City, Iowa: Univ. Iowa Stud. Child Welfare, 1934, 9 (4), 11-74.

Wohlwill, J.F. Developmental studies of perception. Psychol. Bull., 1960, 57 (4), 249-288.

Zagorulko, T.M. & Sollertiaskaia, T.N. Comparative analysis of mechanisms of orienting reflexes. In L.G. Voronin, A.N. Leontiev, A.R. Luria, E.N. Sokolov, & O.S. Vinogradova (Eds.), Orienting reflex and exploratory behavior. Moscow, Acad. Ped. Sci. RSFSR, 1958. Pp. 287-299.