I. Introduction

A number of terms such as adaptation, inhibition, stimulus satiation, as well as habituation have been used to label response decrements that sometimes occur with repeated stimulation. We shall not concern ourselves with any potential distinction between these terms, but only with describing the conditions we think are essential for identifying the phenomenon of primary interest, which we shall call habituation. A critical feature distinguishing habituation from other response decrement phenomena is that the habituated response can be elicited by extraneous

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stimuli that are similar to, but in some way discrepant from, the stimuli to which the habituated response originally occurred.

There are several reasons for anyone concerned with behavior to be interested in habituation. First, it is an example of behavioral plasticity that is common to a wide range of species. Indeed, in some species it is the only demonstrable evidence of behavior modifiability. Second, and equally practicable, habituation has provided one of the better techniques for evaluating the sensory capacity of lower organisms, and also of the human infant. Third, habituation is of interest as a possible manifestation of learning. This last notion, however, has been a matter of some dispute and remains so.

The principle emphasis in research on learning has been on how responses are acquired, i.e., on how responses are attached to new stimuli. Habituation, like inhibition, is characterized by the waning of responses to stimulation. Habituation differs from inhibition, however, in that it refers to the waning of innate or at least long and well-established stimulus–response connections, as opposed to those only recently formed. Inhibition has received little systematic attention and habituation even less. Although the similarities between inhibition and habituation are frequently mentioned, they too are unexplored.

A. HISTORICAL CONSIDERATIONS

Behaviorism undoubtedly had a salutary effect in formalizing a science of psychology. Introspection and mentalistic speculation were properly banned as sources of data. The Pavlovian conditioning model provided both rigor and parsimony. As dissatisfaction with some of the more restrictive tenets of Behaviorism arose, methodological developments made it possible to broaden the range of psychological phenomena that could be investigated, and the learning model continued to dominate.

By now, however, evidence for the effect of the environment on development has to a considerable extent surpassed the explanatory power of the learning model. In many instances neither the necessary contingencies nor the requisite reinforcers can be identified. Furthermore, psychologists interested in learning in general have neither looked for nor expected to find developmental differences in the parameters of learning. Indeed, their stance has been essentially antidevelopmental. Insofar as a developmental difference was expected, it had to do with the interaction of language with learning, particularly with regard to transfer. Otherwise, differences found in learning rate among differing age groups were fre-

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2 Recent exceptions may be found in the work of Papoušek (1967) and in the research reported by Brackbill and Fitzgerald (1969).
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quently dismissed as of little consequence, most probably the result of variations in motivation.

Zeaman and House (1963) made a very significant contribution to the understanding of the development of problem-solving behavior when, in comparisons of the learning rates of retarded and normal children, they discovered that changes in performance could be divided into an attentional and an associational phase. The latter was found to be essentially the same for all children and to occur rapidly, but there was considerable difference in the time taken by different children to "find" the appropriate cues. This difference in attention to cues is undoubtedly also a very relevant factor in changes that are correlated with language acquisition, i.e., language may facilitate the identification of the relevant cues. Thus, the Zeaman and House data, as well as those of others (Fellows, 1968) support the notion that developmental factors do not necessarily affect learning per se, but suggest explanations of age differences in performance on learning tasks in terms of differences in the attentional processes and perceptual development.

It is not sufficient, however, only to identify these differences. One must demonstrate more specifically how these changes come about. It is reasonable to propose that perception and attention are the result of learning, but inasmuch as learning is so difficult to demonstrate at the younger ages, it appears that a learning model would be adequate only if drastically broadened or modified. Therefore, it is reasonable to approach empirically other possible ways of accounting for behavioral plasticity.

It would be fair to acknowledge that there have always been a goodly number of psychologists who were convinced that behaviorism in any of its forms did considerable injustice to man by denying him a mind. These psychologists flouted the principle of parsimony to propose the development of perceptions as opposed to associations, and to speak of actions in place of responses. This position has become more popular with increases in the quantity and quality of both developmental data and data on human problem-solving more generally. This same dissatisfaction also accounts, at least partially, for the increased interest of many developmental psychologists in the works of Piaget. Piaget sees the child as a more active participant in his development than did the behaviorist, and he assumes that the child's behavior is a reflection of the child's construction of his environment. This construction reflects not only the infant and child's experience with the environment, but also the basic structure of a biological organism (Furth, 1969). This view would appear to have merit, yet there is too little known about the conditions under which change takes place. Piaget's concepts of assimilation, accommodation, and equilibration are unsatisfying explanatory devices and say
too little about such elements of cognitive growth as attention, perception, and memory. It is on the development of these latter elements that we intend to focus in this paper, but with particular emphasis on habituation both as a means of assessing changes that take place with stimulus exposure, and as a basic process of perceptual development.

B. Methodological Problems

1. Experience and Perceptual Development
Worden (1966) identified the issue of perceptual development both succinctly and eloquently when he said "In early development, attention meets sense impression, but misses the outer world, whereas, in the adult, attention finds the outer world but largely loses sensory experience [p. 611]." This, of course, represents an empiricist's viewpoint of perception, which does not go unchallenged (Bower, 1966; Fantz, 1965). But we suspect that the nativist-empiricist controversy regarding perception is as irrational in its extreme forms as arguments attributing any broad class of behavior entirely to heredity or environment. It is not unlikely that one will find that specific perceptual skills may differ considerably in the extent to which they are nativistically or empirically determined. For the most part current research on perceptual development has avoided such arguments and has tended to ask questions regarding the sensory capacity of the infant, e.g., are the receptors functioning, and if so, how adequately; and questions regarding the modifications of the nervous system that might account for changes in perception. Answers to the latter question tend to take the form of hypothetical constructs such as cell assemblies, percepts, cognitive structures, and memory stores, as opposed to the identification of specific neural changes. Less formally, one speaks of the organism as "knowing" and of a stimulus as becoming "meaningful." Such statements tend to represent a commitment to empiricism, but with an important distinction. That is, although experience is considered an important variable, it is not assumed to be the only determiner of perceptual development, nor are its effects presumed to occur only within a learning paradigm. The questions of how one might account for change in the organism other than through either physical growth or learning is an issue to which we want to give particular attention through our consideration of habituation as a process complementary to growth and learning.

2. Is Habituation Learning?
In the context of whether perceptual development can be accounted for in terms other than of physical growth or learning, it is necessary to dis-
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tinguish between the strict and loose usages of the term learning. A common definition assigns to learning any behavioral change that is not the result of maturation or transient effector or receptor fatigue. Such a definition would include habituation, but is so all-encompassing that it can contribute little to our scientific vocabulary. The stricter definitions tend to specify learning as occurring in one of two forms. Classical, or respondent, conditioning involves stimulus substitution through the pairing of a neutral stimulus with a stimulus that reliably evokes a response. Temporal parameters of the pairing are critical and relatively well investigated. Operant, or instrumental, learning occurs when certain contingencies are imposed between a response and a reinforcer. If these contingencies are properly arranged, the response will occur with increasing frequency. If the presence of any stimulus is made a part of the response–reinforcement contingency, that stimulus may become discriminative for the response, i.e., the response will occur at a higher rate in the presence of that stimulus than in its absence. As noted previously, however, experimenters have not been particularly successful in demonstrating learning of either type with infants. It may be more accurate to say that for the most part learning has been demonstrated only under rather elaborate conditions (Brackbill & Fitzgerald, 1969; Lipsitt, 1963; Papoušek, 1967) and, when obtained, learned responses in infants are notably unstable. Furthermore, neither classical nor operant conditioning paradigms exactly match those for producing habituation. Therefore, it appears eminently reasonable to investigate changes in behavior such as habituation without preconception as to the basic mechanisms involved. We see no reason to stretch the learning model to fit habituation or to bend habituation to fit the learning model.

3. Variables Controlling Attention

Many who are concerned with perceptual development in infancy are convinced that changes in perception occur relatively early as the result of the child's normal experiences with his environment. The question of how this might happen, particularly if learning is not a major mechanism, is a provocative one. The first assumption we shall make here is that the child will explore his environment on the basis of intrinsic motivation. Classical learning theories had little use for such a notion, and indeed there is a considerable problem in attempting to identify the bases of intrinsic motivation in a noncircular fashion, defining reinforcement is no less a problem, of course. We shall not labor the issue, but suggest that the reader see Hunt (1963), Fowler (1966), or Berlyne (1960). Given that children do attend to and explore their environment, there are fruitful questions that can be asked regarding the variables that control these behaviors. Particularly important is the question, "Why does
a child attend to any particular stimulus?" Sokolov (1963) has an answer for at least part of that question. He assumes that attention is a consequence of the orienting reflex, a well-defined set of physiological responses that occur to any novel stimulus. Sokolov proposed that with repeated exposure to the novel stimulus, a neurological model is constructed. Once this model is established, the orienting reflex will no longer occur, and the child will no longer attend to that particular stimulus unless some component of the complex upon which the model was based is altered and there is consequently a discrepancy between the altered or novel stimulus and the neurological model. Kagan (Kagan, Henker, Hen-Tov, Levine, & Lewis, 1966) expressed a basically similar notion except in terms used by Piaget. That is, he proposed "schemata" in place of neurological models and defined novelty in terms of sufficient discrepancy between the schemata and the novel stimulus to produce one or the other of a set of responses defined much more broadly than the orienting reflex but representing a similar idea. Both of these points of view are in complete agreement on the fact that with repeated stimulus exposure there is a decrement in whatever response is used to indicate attention.

We propose that the decrement described is habituation, and that it is a very pervasive aspect of behavior. It is the first indication of at least a primitive form of memory. If input does not produce an orienting reflex, it is because of a lack of discrepancy between the input and something that is stored as the result of previous exposure to that input. It is of interest, of course, to determine what aspects of the input are stored and what variables influence this selection. Furthermore, one must know more about how changes occur with increased exposure and what factors influence the permanence of what is stored.

Jeffrey (1968, 1969) has speculated that relatively permanent changes in infant perception might result from the habituation of attending responses that occurs with the infant's observation of his surroundings. The young infant's attention is captured by various stimuli, and Jeffrey proposed that it is only through either habituation, the occurrence of a stronger stimulus, or drowsiness and sleep that the infant's attention is released. Given a complex stimulus, component cues will differ in their potential for controlling attention, and with prolonged exposure, habituation to these components will occur in an orderly fashion. With recovery and repeated exposure, the observing responses involved will habituate more and more rapidly until finally the critical cue components are encompassed by a single integrated response. This response, and particularly its neurological components, could be called a percept, schema, or model. With additional experience, these percepts would represent increasingly sizeable chunks of input to which habituation could finally occur. Limits
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on the size of the chunks would in general be the result of the inconsistencies of input surrounding naturally occurring configurations. Such a notion makes explicit at least one way in which perceptual development would occur systematically as the result of what is often thought to be idle exploration.

Our present interest, however, is not so much in models of perceptual development as in basic research on habituation. Inasmuch as habituation is a concept that is frequently utilized but not well understood, it deserves more careful attention as a basic attribute of attention. Although it would not be fair to say that psychologists have been unconcerned with habituation, their concern has been limited for the most part to using habituation as a means of exploring sensory capacity rather than as a basic mechanism of behavioral plasticity or modifiability. We feel that habituation is an important and integral aspect of behavior development and shall proceed to explore what is currently known about the phenomenon in those terms.

4. Critical Characteristics of Habituation

Our concern is not with response decrement per se but with response decrement resulting specifically from habituation. It is therefore necessary to specify ways to ensure that an observed decrement in response reflects more than temporary adaptation or fatigue. Thompson and Spencer (1966, pp. 18–19) listed what they refer to as “parametric characteristics” which, if met, should exclude other more temporary response decrements and therefore provide a critical definition of habituation of behavior. These are:

1. Given that a particular stimulus elicits a response, repeated applications of the stimulus result in decreased response (habituation). The decrease is usually a negative exponential function of the number of stimulus presentations.

2. If the stimulus is withheld, the response tends to recover over time (spontaneous recovery).

3. If repeated series of habituation training and spontaneous recovery are given, habituation becomes successively more rapid (this might be called potentiation of habituation).

4. Other things being equal, the more rapid the frequency of stimulation, the more rapid and/or more pronounced is habituation.

5. The weaker the stimulus, the more rapid and/or more pronounced is habituation. Strong stimuli may yield no significant habituation.

6. The effects of habituation training may proceed beyond the zero or asymptotic response level, i.e., recovery may occur more slowly.

7. Habituation of response to a given stimulus exhibits generalization to other stimuli.
8. Presentation of another (usually strong) stimulus results in recovery of the habituated response (dishabituation).

9. Upon repeated application of the dishabituating stimulus, the amount of dishabituation produced habituates (this might be called habituation of dishabituation).

The characteristics indicated in Items 1, 2, 4, 6, and 7 are descriptive of habituation, but do not distinguish it from receptor adaptation or effector fatigue. Item 5 is more critical in that a weaker stimulus should not lead to either quicker adaptation or fatigue. Items 3, 8, and 9 appear to provide a reasonable basis for ruling out effector fatigue and receptor adaptation. Item 3 states that with repeated episodes of habituation training followed by spontaneous recovery, habituation becomes successively more rapid. Item 8 refers to the phenomenon of dishabituation, which occurs with the presentation of an extraneous stimulus, and item 9 refers to the habituation of dishabituation. Items 3 and 9 have something in common in that each specifies an effect of some permanence with repeated habituation or dishabituation, and thus each points to a more permanent modification of the organism than implied by either effector fatigue or receptor adaptation.

The classical notion of dishabituation refers to the recovery of an habituated response to the original stimulus following the presentation of an extraneous stimulus, usually a fairly strong stimulus. Such recovery does not necessarily rule out sensory adaptation or effector fatigue, particularly if Thompson and Spencer are correct in suggesting that the mechanism is more likely sensitization than dishabituation.

There is another characteristic that has also come to be called dishabituation that does not meet this classical definition, but nevertheless may be an even better criterion for habituation, and is most certainly a phenomenon that is of critical interest to the developmental psychologist and cognitive theorist. We refer to the fact that a slightly discrepant or novel stimulus, which may be even weaker than the original stimulus, may itself elicit a previously habituated response. This effect provides a very strong basis for assuming habituation, and it is this paradigm that has been used in most of the studies we shall review. Whether this effect should be called dishabituation is not nearly as critical as is the fact that experimental situations with proper controls can provide a sound basis for inferences about perceptual and cognitive development within a model of behavioral plasticity that is so simple in its characteristics that it can occur in the simplest organism and, moreover, occurs as a natural and inevitable consequence of contact with the environment. Thus, in what follows we will be concerned both with the parameters of habituation and with what may be indicated regarding perceptual development by use
of the habituation paradigm, along with the procedures that various experimenters have introduced to assure proper assessment of habituation.

II. Research on Habituation

A. Habituation to Auditory Stimulation

Most investigations involving habituation to auditory stimulation are relatively recent. The first appears to be a study done in the Soviet Union around 1950 by Bronshtein and Petrova (1967). Like so much Soviet research, it is poorly reported. Not only is there inadequate detail, but there are inconsistencies among the details given. For example, although the cycle of stimulation is indicated in the text to be .5 second on and 1 second off, a copy of a record that accompanies the text indicates that the sound is on longer than it is off, and furthermore, that these intervals are quite variable, e.g., the tone is on in one instance three times as long as it is off. Nevertheless, both the technique and the data they reported are interesting.

Bronshtein and Petrova sought to answer two questions, both classic in the psychology of infancy. The first has to do with whether the neonate can hear, the second with whether the cortex is functional. Without going into the reasons for suspecting that the neonate might not be able to hear, evidence that the ears were functional at birth was frequently rejected because of the failure of some experimenters to control visual and tactual cues associated with sound production which permitted responses to be attributed to those cues. Failure to have sufficiently sensitive indices of hearing may have accounted for the lack of results of other experimenters. In answer to the question of whether the newborn hears, the work being described, as well as some additional work by Bridger (1961), leaves little doubt that the auditory apparatus is functional, at least in most newborns. The answer to the question regarding the cortex does not come so easily, as we shall see from the studies that follow. Besides its priority, the Bronshtein and Petrova study is of special interest because it used a novel measure, the suppression of sucking, as an indication of perception. The rationale for this measure is based upon the fact that ongoing behavior is commonly interrupted by the perception of an extraneous or novel stimulus.

Reflexive nonnutritive sucking occurs in bursts of 3 or 4, to 20 or 30 sucks in a burst, and at a rate of a little less than 2 sucks per second. The burst lengths and interburst intervals are variable both within and between infants, but little is known of the variables that control either burst length
or interburst interval. The stimuli Bronshtein and Petrova used were generated by organ pipes, a harmonica, a whistle, and sometimes the tap of a pencil on a table. These sounds were said not to exceed 60 to 70 db in intensity, and were presented in bursts of four impulses with a reported 0.5-second pulse duration, a 1-second interval between impulses, and an interval of 1 to 2 minutes between bursts. One group of 33 infants ranged in age from 2 hours to 8 days. A second group of 10 infants was tested over a period from 1 to 5 months of age, with some infants, but not all, tested repeatedly. Sucking suppression was reported in all ten of the older children and in 29 of 33 of the younger infants. Therefore, the investigators conclude that infants are able to hear at birth.

Bronshtein and Petrova (1967) also looked at habituation of the sucking suppression and found that the "extinction" of the reaction to sound proceeds in a regular fashion. That is, after some number of trials, the sound failed to suppress sucking. For a total of seven children this occurred in as few as three trials: for nine, it took eight or more trials. Their method of data presentation does not permit any precise statement as to differences in habituation with age. They noted that habituation frequently had an "undulating character," in that suppression would occur again on occasion "without the apparent influence of outside agents [p. 169]." They also observed recovery over time as well as through the presentation of novel stimuli. No systematic data were reported on recovery, however, and their comments about dishabituation were minimal. They cite other Soviet data to support the contention that habituation is controlled by the cortex, and concluded that their habituation data indicate cortical function, at least to some degree, from the first day of life. This conclusion is controverted, however, by recent data indicating that habituation is not necessarily a cortical phenomenon (Galambos, Sheatz, & Vernier, 1956; Hernandez-Peon & Scherrer, 1955).

A study establishing habituation of both heart rate acceleration and startle to auditory stimulation, and also pitch discrimination, was done in the United States by Bridger (1961). Although the research design appears more rigorous, it suffers, like that of Bronshtein and Petrova, from inadequate reporting of a number of details. Bridger was searching for a technique discriminating individual differences at birth or shortly thereafter. Sensory capacity and habituation were chosen as two measurable indices of neurological development. His subjects were 50 normal infants from 1 to 5 days old. He reported that the startle response, as assessed by three observers, habituated most quickly when the tone–intertone interval duration was 20/5 (i.e., the duration of the tone was 20 seconds and the intertone interval was 5 seconds) as compared with tone–interval durations of 20/10, 5/5, or 5/3. No comment was made regarding the num-
ber of babies on which this conclusion was based, the reliability of the observations, nor whether order effects were controlled. A figure showing the effects of different intervals on one infant indicate faster habituation with successive exposures under the various intervals indicated above. Inasmuch as the last interval was 20/5, a pattern already identified as being optimal, Bridger's interpretation of faster habituation with repeated stimulation is not unambiguous.

Bridger (1961) indicated that the heart rate data confirmed the observational data, but he did not present the heart rate data. The intensity of the tone was not reported except to say that it was kept at a level that was intense enough "to overcome the role of the state of the baby... no matter whether the baby was deeply asleep or vigorously crying [p. 992]." How habituation could be obtained at all under these conditions becomes increasingly difficult to understand when one reads the statement: "However, some babies when crying or asleep did not respond to the most intense stimulus and we always had to vary the interval or novelty of the stimulus to determine whether the infants' cessation of responding was due to habituation and not a temporary shift in state of arousal [p. 992]." Bridger reported two levels of habituation—first, the disappearance of the marked startle reaction and then somewhat later, if at all, cessation of responding. Cohen (1969b) has suggested that two responses may be made to a stimulus, one related to orienting, another related to processing. He suggested that the latter may habituate, whereas the former may not. Bridger appeared to find the opposite result, but it may be that the startle reaction to which he referred is specifically startle and should not be related either to more normal alerting or perceptual processing.

Bridger obtained relatively impressive results in testing for discriminative capacity. Using a tone duration of 40 seconds and a ½-second inter-tone interval, he switched frequency after three consecutive no response trials. Reoccurrence of the habituated response indicated that 15 (out of 50?) babies were discriminating among frequencies. Although the difference thresholds were quite variable among babies, one baby was reported to be able to discriminate between tones of 200 and 250 Hz.

One cannot be entirely certain that the response decrement that Bridger observed was habituation, although the fact that the habituated response could be elicited by a discrepant stimulus, from the same stimulus dimension, if not a regression to the mean effect, would provide rather convincing evidence that habituation was observed. In reiterating that the Bridger study leaves much to be desired with regard to rigor, it is equitable to point out that rigor does not come easily in the study of the human infant.
In a series of studies more carefully designed than those of either Bronshtein and Petrova or Bridger, Bartoshuk (1962a,b) was concerned specifically with habituation as an important aspect of development. As can be seen in Fig. 1, he found a reliable response decrement of neonates' heart rate acceleration to auditory stimulation of 1 second duration, but he found no difference between groups that received the auditory stimuli at 15-, 30-, or 60-second intertone intervals. He argued that the lack of difference with different tone intervals supported an habituation rather than a fatigue interpretation of the response decrement in that if fatigue had been a factor, one would have expected greater response decrement with the shorter intertrial intervals. It may be, however, that all of these intervals were too great for fatigue to be a factor, in that each interval provided sufficient time for fatigue to dissipate. This argument, of course, does not contradict an habituation explanation, but only questions Bartoshuk's reasoning.

In a second study, with 6- and 60-second intertone intervals, Bartoshuk explored dishabituation as a function of intensity changes and frequency changes. A tone of 500 square wave pulses per second for a duration of 1 second on and 1 minute off was presented to 30 neonates. The intensity of this tone was approximately 80 dB for the first 17 trials. On trial 18 the intensity was increased to 91 dB. On trial 19, 20, and 21 the intensity was reduced to 80 dB and then on trial 22 the frequency was changed to 5 pulses per second (at 80 dB). On trials 23, 24, and 25 the initial stimulus of 500 pulses per second at 80 dB was presented. These same stimuli were presented to a second group of 30 neonates, but at 6-second inter-
vals. After 16 minutes of such presentation there was a 1-minute pause, then a 91 dB tone was presented of the same frequency and duration as the habituating stimuli. This was followed at one minute intervals by three additional presentations (trials) of the tone at 80 dB, and finally by a tone of 5 pulses per second at 80 dB as for the first group. The test for dishabituation with a 91-dB tone was given only after a 1 minute rest following 16 minutes of stimulation. All subsequent stimulation was at 1-minute intervals and included on trials 18, 19, and 20 a return to the 80-dB level and on trial 21, a tone of 5 pulses per second at 80 dB as for the first group.

The evidence for habituation was substantial in both groups as was recovery of the response to the more intense tone. The fact that there was continued greater responding on the trials following the dishabituating stimulus during which the tone was presented at the original level demonstrates dishabituation and tends to obviate a fatigue explanation. Bartoshuk points out, however, that this high level of responding may also be attributable to a general rise in arousal level or to posttetanic potentiation in the auditory system (Hughes, 1958). Of particular interest is the failure to find any evidence of response to changes in the frequency of the tone. This contrasts markedly with Bridger's findings, but rather gross differences in the experimental conditions, particularly with regard to the duration of the stimulus and the intertrial interval, might account for the differing results of the two studies.

In a third study, Bartoshuk (1962b) approached the problem of frequency discrimination in another way. The stimulus was a tone varying monotonically in pulse frequency from 100 to 1000 pulses per second. Voltage was kept constant; therefore, there was a correlated increase in intensity with change in frequency. The median intensity was reported as 85 dB. The duration of the stimulation on each trial was 8 seconds with a 60-second interval between trials. Following either 51 or 61 trials of stimulation with the ascending series, the stimulus pattern was presented for 10 trials in reversed order, i.e., from 1000 to 100 pulses per second. The results of this experiment were somewhat equivocal. Only if the data from the 10 neonates that showed greatest habituation were used, was there an indication of a response to the reversal of the stimulus. Bartoshuk felt that these data do, however, rule out a fatigue interpretation of the response decrement. However, he noted that any heart rate change that occurred took place in the first 4 seconds of stimulation. Thus, the habituation was occurring in a response to stimulus onset and therefore, even though the average intensity difference was the same over 8 seconds of stimulation, intensity at onset was quite different for the ascending and descending stimuli, with the descending stimulus having
a more intense onset. Therefore, sound intensity was not effectively controlled. Although it is difficult to relate their data to Bartoshuk's, Eisenberg, Coursin, and Rupp (1966) reported a correlation between heart rate and the progression of tones in a series. They reported that heart rate increases as the frequency goes up and decreases when it goes down, and they obtained evidence in neonates of habituation to a descending tone which generalized to an ascending tone.

A study by Keen, Chase, and Graham (1965) was designed to measure the permanence of habituation by testing infants for residual habituation 24 hours after the original habituation trials. Heart rate change was used as a measure of perception. Interstimulus intervals were long (90 seconds) in order to assure the return of the heart rate to a normal level between stimulations. This is half again as long as the longest interstimulus interval used by Bartoshuk and many times longer than the interstimulus interval Bridger thought to be optimal. The choice of stimulus duration was apparently a compromise between the durations used by Bridger and Bartoshuk. That is, for one group the stimulus duration was 2 seconds, and for the other group it was 10 seconds. For reasons that are not clear, the stimulus duration was switched for each group on the second day, a condition hardly optimal for showing residual habituation in that it is possible that the change in stimulus duration itself might be dishabituating. This did not prove to be the case, however. The results at first glance appear to be quite positive. There was habituation of the duration of the heart rate accelerative period to the longer stimulus on the first day, but not to the shorter. Although Keen et al. concluded that there was evidence of residual habituation on the second day, this "residual habituation" appeared in the group that did not show habituation on the first day! In light of the data that follow indicating the effect of the state of arousal of the infants on heart rate reactions to stimulation, it appears likely that the above data may be more readily attributed to differences in levels of arousal rather than to residual habituation.

S. J. Hutt, Hutt, Lenard, von Bernuth, and Muntjewerff (1968) found that the likelihood of eliciting startle was greatest for square waves, next for a human voice, and least for sine waves, and that the largest electromyographic responses occurred at 125 Hz. They also found, as had Lewis, Bartels, and Goldberg (1967) with tactile stimulation, that the magnitude of the response was positively related to the state of arousal of the infant. It was largest when the infant was wide awake and least when the baby was asleep. Given these data, C. Hutt, von Bernuth, Lenard, Hutt, and Prechtl (1968) presented three different stimuli repeatedly: square waves at 12 pulses per second, the human voice saying "baby," and a 125 Hz sine wave, each with 75-dB intensity at the neonate's ear, to see whether
Habituation would occur differentially among these stimuli. Unfortunately, in spite of their awareness of the importance of the state of arousal of the infants, the correlation of the response with state made it impossible to interpret the response decrements observed as being attributable to anything but change in state of arousal. This is not too surprising when one considers that the testing procedure typically does not start unless the baby is awake. Furthermore, the commotion surrounding placing the infant in a special situation and attaching electrodes increases the likelihood that he will be aroused early in the procedure. However, inasmuch as the neonate is never fully awake or asleep for any prolonged period, he is less likely to be aroused toward the end than at the beginning of a brief stimulation period. Therefore, it may be that assertions regarding habituation should be made only when state is controlled or partialled out in some way.

In a subsequent study, Graham, Clifton, and Hatton (1968) measured heart rate changes to auditory stimulation on 15 trials per day over 5 successive days. Their stimulus was not markedly different from the square wave stimulus used by C. Hutt et al. The data from this experiment were consistent in displaying heart rate acceleration. In this instance, and in contrast with the Keen et al. (1965) data, no change in the duration of acceleration was found, either within or between sessions, that could not be accounted for in terms of the changes in arousal.

In another study, Clifton, Graham, and Hatton (1968) varied the duration of stimulation and found an inverted U-shaped relationship between duration and peak amplitude, peak latency, and response duration. Insofar as there was any habituation over trials, it appeared to occur with longer stimulus durations; overall evidence for habituation, however, was meager.

The studies reported so far tend to suggest that habituation of heart rate acceleration is not very likely to occur in the neonate except under very special circumstances. Graham and Clifton (1966) have made the additional point that heart rate acceleration as seen in the neonate is undoubtedly a manifestation of a defensive reflex rather than an orienting reflex. Whether an orienting reflex does exist in the neonate is problematical, and if it does, it would appear reasonable to question whether the usual physiological indicators do habituate. Certainly the heart rate data shows very little in the way of habituation that cannot be accounted for by changes in the neonatal infants' state of arousal.

Studies of habituation using older infants provide more impressive results. Hatton and Graham (1969) found a marked change in the form of the heart rate response to auditory stimulation between 6 and 12 weeks of age, and they suggest that the evidence indicates "... a developmental
change in heart rate response which is independent of concomitant changes in sleep-wake state [p. 6]." It is not quite clear what they mean by that statement inasmuch as changes in sleep-wake cycles also reflect the sort of neurological maturation that may well be basic to a mature orienting reaction. Nevertheless, given strong heart rate deceleration to auditory stimulation by three months of age, it is of interest so see if this response is more likely to habituate than the characteristic accelerative response of the neonate.

Support for habituation of the decelerative response was provided by Clifton and Meyers (1969) who reported habituation over 15 trials with 4-month-old infants. It was not as regular as one might have hoped, however. They also reelicited the decelerative response by switching from a continuous to a pulsed tone or vice versa. Interestingly enough, the response was apparent for only one trial, a result that is consonant with data on much more mature organisms.

Most of the research with auditory stimulation has been of a methodological nature. The last two studies we shall cover are concerned specifically with questions of perceptual development. Moffitt (1968) used the habituation paradigm to test infants' ability to discriminate subtle differences among speech sounds. His stimuli were two electronically generated stimuli that sounded much like the phonemes DAH and GAH. These two phonemes differ only during the first 60 msec and then only in the second of three formants that make up the sounds. The second formant for /g/ starts approximately 1000 Hz higher than the steady-state portion of the sound, but the second formant for /d/ starts 150 Hz below the steady-state portion of the sound. This appears to be a relatively subtle discrimination. Moffitt tested 30 infants ranging from 20 to 24 weeks of age. Habituation of heart rate deceleration to one phoneme and occurrence of deceleration upon presentation of the other phoneme were used to evaluate the infants' ability to discriminate between DAH and GAH. In general, the results supported the conclusion that 20- to 24-week-old infants are capable of such subtle discriminations.

An important question that has been studied relatively little with auditory stimuli, but as we shall see later, somewhat more with visual stimuli, is the relation between the discrepancy between stimuli and the likelihood of obtaining an orienting reaction to one stimulus following habituation of the orienting reaction to the other. Melson and McCall (1970) varied the discrepancy between stimuli by varying the serial order of a series of eight tones played on a piano. The basic series was a C major ascending scale played at the rate of one note per second. The variant scales were produced by transposing the first and sixth notes or by reordering all of the notes. The subjects were 48 5-month-old girls, and the response was
heart rate deceleration. Fast habituators showed a clear response to the discrepant stimuli. The larger discrepancy did not produce a larger response than the smaller discrepancy, but rather produced slower habituation with repeated presentations. This study shows response to stimulus complexity of an unusual sort in that it involves an engram of a serial nature, and it suggests an ability relevant to language processing that certainly considerably precedes any evidence of such discriminations in language usage.

B. Habituation to Visual Stimulation

Studies of habituation to visual stimulation differ in several important respects from studies of habituation to auditory stimulation. First, the variety of stimulation is much greater. Infants have been exposed to visual inputs varying in color, form, size, degree of movement, number of squares, or number of angles. In addition, the stimuli have ranged in complexity from simple geometric forms such as squares or circles, to complex photographs, magazine pages, and three-dimensional mobiles.

The second important distinction between studies of auditory and visual inputs involves the number and type of response measures employed to assess habituation. There are no direct techniques for measuring stimulation of acoustic receptors. Therefore, studies of auditory perception have had to rely upon such indirect measures as sucking suppression or heart rate change. Although these response measures have also been included in some investigations of visual stimulation, direct observation of infants' eyes has also been possible, with the exception perhaps of newborns where some doubt exists as to conjugate fixation ability.

A final distinction between investigations of habituation to visual as opposed to auditory stimulation is that research on visual stimulation is typically done with older infants. There are very few reports of attempts to habituate neonates, or even infants under 2 months of age, to visual patterns. It would appear, however, that infants under 2 months of age do not habituate to visual stimulation. In fact, as we shall see, some evidence suggests that at 6 weeks an infant's visual fixation time may actually be greater to a familiarized pattern than to a novel one.

Along with the research on habituation of sucking suppression to acoustic stimuli, Bronshtein, Antonova, Kameneteskaya, Luppova, and Sytova (1958) also reported habituation to a bright light. Their description of both the procedure and results of their visual stimulation experiments is even sketchier than that of their auditory experiments. Haith (1966) attempted to replicate and extend the Bronshtein et al. findings, but with methodological improvements in the sucking suppression measure. Following a 5-second baseline period during which one stationary light was
presented, Haith's neonates were randomly given either a 5-second continuation of the stationary light or a 5-second exposure to a moving light. Inasmuch as greater suppression of sucking occurred to the moving than to the stationary light, the infants must have been attending to the stimuli. Nevertheless, there was no evidence of habituation over trials.

In a later experiment with 2- to 4-month-old infants, Haith, Kessen, and Collins (1969) again failed to find habituation of sucking suppression to a moving light. Even though they did not find a decrease in suppression, ample evidence now exists that other responses of infants 3 months of age or older do show a decrease with repeated presentation of a moving light. Whether or not these response decrements can legitimately be called instances of habituation, however, is still open to debate, as will become apparent.

In an extensive study of infant attention, Kagan and Lewis (1965) exposed 24-week-old infants to a blinking light that either remained stationary, moved horizontally, or described a square helix pattern. Fixation times decreased dramatically from the first to the fourth occurrence of each stimulus. There was also some tendency toward a reduction in heart rate deceleration over trials, but this change was not nearly as striking as that found in the fixation time data. In another portion of their study they reported reductions over trials in heart rate change and fixation time to other types of visual inputs such as pictures of faces, a panda bear, a bottle, a bull's eye, and a checkerboard. Unfortunately, Kagan and Lewis did not follow their habituation trials with the presentation of a novel stimulus to test for recovery of the response. As a consequence, one cannot determine whether the decrease they found resulted from repeated exposures to the same stimulus, was specific to that stimulus, and therefore could be labeled habituation; or whether the decrease was produced by an increase in the infants' fatigue or irritability in the testing environment as the experiment progressed.

In two experiments, Lewis and his associates (Lewis, Bartels, Fadel, & Campbell, 1966; Lewis, Goldberg, & Rausch, 1968) refined the Kagan and Lewis procedure somewhat in order to test for response recovery. In both experiments, the infants were exposed to four 30-second habituation trials with either a stationary or moving blinking light followed by one trial with the opposite type of light. Infants from 3 to 18 months of age were tested in order to investigate developmental changes in rate of habituation. Response decrements in both fixation time and heart rate deceleration were obtained over the four habituation trials, and the rate of this decrement was directly related to age; the older the infant, the more rapid was the decrease in responding over the four trials. Unfortunately, with one possible exception, no recovery in responding was
obtained when the novel stimulus was presented on trial 5, so it is possible that these decreases may not have been stimulus specific and, therefore, not habituation.

Their failure to obtain unambiguous habituation may be an indirect result of their attempts to record heart rate changes along with fixation time. An infant's heart rate deceleration to either the onset or offset of a stimulus does not occur immediately. Several seconds must elapse before maximum deceleration is reached and several more seconds before the infant's heart rate returns to baseline. For this reason, when heart rate is the dependent variable, fairly long intertrial intervals are necessary. The intertrial intervals in the Kagan and Lewis experiment were 12 seconds, and they were 30 seconds in the Lewis et al. investigations. If the short-term memory of infants is not sufficient to bridge the gap between stimulus presentations—Watson (1967) and Lewis (1967) estimated it to be approximately 5 seconds—one would not expect habituation to occur.

Cohen (1969a) also investigated habituation of infant visual fixations to a moving blinking light. He gave more habituation trials than were used in the earlier studies (20 trials instead of four) and used a shorter intertrial interval (5 seconds instead of 12 or 30 seconds). He also found a decrease in responding over trials, with 5-month-old infants showing a more rapid rate of decrease than 3-month-olds. To control for possible situational fatigue or irritability, an additional group of infants was exposed to the laboratory situation for the same length of time but did not receive the blinking light until the last five trials. Their response to the light on these five trials was just as great as the other infants' response on their first five trials, thereby indicating that the decrease over trials was related to the repeated exposures of the blinking light.

Although there was no test for recovery in the Cohen study, it appears very unlikely that the observed response decrement can be attributed to receptor adaptation, in that by the end of habituation the infant was spending little time fixating the stimulus, and even when he did fixate, his fixation point was not constant but rapidly changed as he scanned the visual pattern. Effector fatigue, however, cannot be ruled out in the Cohen investigation. It may be that the fact of looking at a visual stimulus requires greater use of muscles of the eye, head, neck, and other body parts, than the act of not looking. Those muscles may have fatigued more in the infants who had been watching the stimulus for 20 trials than in the infants who were not shown the stimulus during those trials. If effector fatigue reduces subsequent fixations, Cohen's results may have resulted from such fatigue rather than being an instance of habituation.

The research with moving light patterns, while not conclusive, suggests that infant habituation to visual stimulation first occurs at approximately
2–3 months of age. Additional research using other varieties of visual inputs leads to a similar conclusion. At least it suggests that an infant’s preference for novel over familiar stimuli is gradually acquired and is not clearly present until sometime after 2 months of age. Fantz (1964) presented photographs or advertisements cut from magazines to infants from 1 to 6 months of age. Two patterns were presented simultaneously on each of the 10 successive 1-minute trials. One of the two patterns remained constant for all trials, and the other was varied from trial to trial. Figure 2 shows his results. As trials progressed, infants over 2 months of age tended to look a greater proportion of the time at the novel, changing pattern. According to Fantz, the decreasing fixation to the familiar stimulus was accompanied by increasing fixation to the novel one, resulting in a high overall fixation rate throughout the entire test. That fact obviates a fatigue explanation of the decrease in fixation time to the one stimulus. Whether or not the decreased responding to the familiar pattern is accepted as an instance of habituation, however, depends upon whether the decrease was produced solely by the repeated presentations of the constant pattern or whether it was the result, at least in part, of the simultaneous occurrence of the competing novel pattern. Only the former explanation would be consistent with the definition of habituation.

Fantz’s data suggested little or no preference for either novelty or familiarity in infants under 2 months of age. More recent evidence (Greenberg, Uzgiris, & Hunt, 1970; Uzgiris & Hunt, 1970; Weizmann, Cohen, & Pratt, 1971) suggests that if infants of this age are given long-term exposure to a pattern, they may actually come to prefer a familiar

Fig. 2. Change in relative duration of fixation of a repeatedly exposed (constant) pattern relative to a novel (variable) pattern (the position of each being controlled) during a series of exposure periods. Each curve is the mean for six to eight infants (from Fantz, 1964).
visual stimulus. In the most convincing of these experiments, Weizmann et al. exposed the same mobile to infants beginning at 4 weeks of age for 30 minutes a day. When tested with the familiar and a novel mobile at 6 weeks of age, the infants fixated reliably longer on the familiar one. At 8 weeks of age, the preference for the familiar disappeared and was beginning to be replaced by a preference for the novel mobile. Habituation requires greater responding to, or preference for, novelty than familiarity.

Just as some investigations have found a reduction in responding over trials but no increase in response to a novel stimulus (e.g., Lewis et al., 1966), others have found response to a novel stimulus even though no reduced responding occurred during the habituation phase of the experiment. For example, Meyers and Cantor (1967) familiarized 6-month-old infants for 16 trials to a photograph of either a ball or a clown. Each habituation trial was 7 seconds long and was followed by a 7-second intertrial interval. Sixteen additional trials, eight with the familiarized stimulus and eight with the novel one, were then presented to test for recovery. No reliable changes in either heart rate or fixation time occurred during the habituation phase; however, during the test phase, heart rate deceleration in males was significantly greater to the novel than the familiar photograph. McCall and Kagan (1970) found similar changes in fixation time in the 4-month-old infants they called “short lookers.” These were a group of infants who did not exhibit a decrease in responding with repeated exposures of the same stimulus, but exhibited increased fixation times when presented with a novel stimulus. In addition, they reported, as did Meyers and Cantor, recovery of heart rate deceleration, but again only in male infants.

Up to the present time only one investigation (Pancratz & Cohen, 1970) has counterbalanced the visual stimuli used in habituation and test phases of the experiment. Both a decrease in responsiveness during the habituation phase and recovery of the response to a subsequent novel stimulus was found. Four-month-old infants were presented with simple geometric patterns—a red square, a green circle, a blue triangle, and a yellow rod—and fixation time was taken. Ten familiarization trials with one of these patterns, chosen randomly, was followed by six test trials, during which the familiar pattern and each of the other three novel patterns were alternately presented. Each trial lasted 15 seconds and was followed by an intertrial interval of approximately .5 second. The time interval between the end of the habituation phase and the beginning of the test was also varied, but because only unambiguous recovery occurred when the test immediately followed habituation, only those data are reported here.

Figure 3 presents the habituation data separately for males and females.
As can be seen, the males exhibited rapid habituation to the geometric pattern, but the females did not. In the test phase of the experiment, the males showed clear evidence of discrimination by responding on an average of 6.9 seconds to the novel stimulus and only 2.4 seconds to the familiar one. As might be expected, the females, who as a group had not habituated, also did not respond differentially in the test to the novel and familiar stimuli (5.5 seconds vs. 5.3 seconds).

The Pancratz and Cohen experiment is important in that it was the first unequivocal demonstration of habituation to visual stimulation in infants. Although McCall and Kagan's (1970) "rapid habituation" group appears to have demonstrated habituation, only infants who showed decreased responding during the habituation trials were given a test for recovery, and therefore the responses to the novel stimulus might be attributable to a "regression to the mean" effect. Other experiments (Caron & Caron, 1969; Saayman, Ames, & Moffett, 1964) also have revealed both habituation and recovery to a novel stimulus. However, the stimuli involved in these studies were not counterbalanced, therefore even though the elevated response to the novel stimuli provides evidence for discrimination, one cannot rule out a fatigue explanation for the response decrement observed inasmuch as response levels may have been much higher to these stimuli originally.

Although we have indicated that in general any stimulus that is suffi-
ciently discrepant or novel to be discriminated should elicit the previously habituated response, Hunt (1963) and McCall and Melson (1969) suggested that this is not necessarily true. They proposed that at least with pattern perception, attention to a novel pattern will be an inverted U-shaped function of the discrepancy of the novel pattern from the familiarized stimulus. According to this view, maximal responding should occur to those stimuli that are only moderately discrepant or novel.

Whichever position is correct, it would be worthwhile, following repeated exposure of one stimulus, to vary systematically the novelty of a second stimulus and to examine response recovery. Several experimenters have attempted this. Not all report habituation, but all do indicate different levels of responding for different degrees of novelty.

McCall and Kagan (1967) and McCall and Melson (1969) used the stimuli shown in Fig. 4. Beginning at 3 months of age, infants in the McCall and Kagan study were exposed to pattern A for 20–30 minutes a day in their homes, 4–6 times per week. At 4 months, the infants were tested on patterns A, B, C, and D. A control group who did not have prior experience with pattern A was also tested at 4 months on all four stimuli. Differences were found in heart rate deceleration to the patterns, but only in female infants who had experienced pattern A in the home. The girls exhibited greater deceleration to patterns C and D than to B, although deceleration to B was still greater than to A. According to adult ratings, patterns C and D are more discrepant from pattern A than is pattern B. McCall and Kagan (1967) concluded that the “magnitude of cardiac deceleration was an increasing function of the degree of discrepancy between an adapted stimulus and figures which were graded discrepancies from that standard [p. 388].” Recently, McCall and Kagan

Fig. 4. The four test stimuli in order of discrepancy from the standard (from McCall & Kagan, 1967).
(1970) confirmed this result, using somewhat different stimuli and a fixation time measure. This would not necessarily contradict Hunt's notion of an inverted U-shaped function, inasmuch as the stimuli fell within a relatively limited range, thus possibly not including a sufficiently discrepant stimulus.

In the McCall and Melson (1969) investigation, 5½-month-old boys were exposed to pattern A and then tested on A, B, C, and D. Again, differences in heart rate deceleration to the test stimuli were found. However, unlike the female infants in the McCall and Kagan (1967) study, these male infants showed the greatest deceleration to the pattern which was the least discrepant from pattern A. Whether or not the conflicting data in these studies result from differences in the sex of the subjects, differences in procedure, or some combination of both, is unknown. The results do suggest that the level of discrepancy from the habituation stimulus may be a critical factor in determining if the habituated response will be elicited.

Other investigators have examined generalization of habituation to simple geometric forms. Saayman et al. (1964) measured 3-month-old infants' visual fixations to pictures of red and black circles and crosses. Following a 4½-minute familiarization period with one of the stimuli, infants were simultaneously shown the familiar stimulus and a novel one differing in either color, form, or both. The only group to show greater responding to the novel than familiar stimulus on the postfamiliarization test appeared to be the infants given the pattern differing in both color and form. The specific comparison of novel and familiar stimuli was not tested statistically, but other mean differences of similar magnitude were significant. The generality of these findings may be limited, however, since the group later given the novel color and form pattern tended to fixate more during habituation than did the other groups, even though the other groups were also habituated to the same stimuli. Therefore, one cannot be certain that the recovery found in the novel-color novel-form group was a function of the greater novelty of the recovery stimulus in that group, and not a function of the greater exposure of the familiar stimulus to the group during the habituation phase of the experiment.

A similar experiment (Cohen, Gelber, & Lazar, 1970) also measuring infant visual fixations has recently been completed. The experiment was divided into an habituation and a discrimination phase. During the habituation phase, 64 infants were randomly assigned to four groups in which they received twelve 15-second trials with either a red circle, a red triangle, a green circle, or a green triangle. During the discrimination phase, all infants received successive 15-second presentations of all four stimuli. Thus, they received either the habituation stimulus, or a stimulus with a
novel color but familiar form, a novel form but familiar color, or both a novel form and a novel color. Figure 5 presents both the habituation and the response to the novel stimuli for male and female infants. There was marked habituation over trials, and the response was reelicited with the presentation of a novel stimulus. Least change in the habituated response occurred when only the color or form was changed, the most when both were changed.

While the data for girls parallel those for boys, the differences in the responses of the girls to the four stimuli are not nearly as large as for the boys. One reason may be the apparent lack of habituation in female infants. This sex difference in rate of habituation tends to replicate similar findings reported earlier in the Pancratz and Cohen experiment.

In summary, with one exception (McCall & Melson, 1969), the evidence on generalization of habituation supports the conclusion that the more discrepant the dishabituation stimulus is from the one exposed during habituation, the greater the recovery will be. This conclusion must be qualified in that all of the experimenters examining generalization so far have tested infants 4 months of age or older. It is quite possible that the response of younger infants might follow the inverted U-shaped pattern predicted by Hunt (1963), attending most to a moderate discrepancy. It is also possible that even the most discrepant stimulus employed in the studies mentioned above is only a moderate discrepancy for 4-month-old infants, and if more highly discrepant stimuli had been used, 4-month-old infants might also have responded in a manner consistent with the inverted U-shaped prediction.

The generality of results from infant visual habituation experiments must also be qualified somewhat due to the several instances in which
sex differences were obtained. Although the underlying reasons for these differences are unclear, a definite pattern in the results is emerging. The pattern was first described by Weizmann et al. (1971). These investigators not only tested infants’ fixations to novel and familiar mobiles, but also did the testing in either novel or familiar bassinets. Although both boys and girls preferred the familiar mobile at 6 weeks regardless of the type of bassinet, the results were more complicated at 8 weeks. Weizmann et al. had predicted that if an infant was going to display a preference for novelty, that preference would be stronger in a familiar bassinet, since there would be fewer novel elements in the environment to distract the infant from the novel mobile. The prediction was confirmed, but only for male infants. The 8-week-old boys showed a reliable preference for the novel mobile when in the familiar bassinet, and no consistent preference when in the novel bassinet. The 8-week-old girls, contrary to all predictions, did just the opposite. Their only preference for the novel mobile occurred when they were in a novel bassinet. The girls did not respond reliably more to either mobile when in the familiar bassinet.

An examination of other literature in this area reveals that in most cases where sex differences were found, the pattern was consistent with that reported by Weizmann et al. Both Pancratz and Cohen (1970), and Cohen et al. (1970) found greater habituation and recovery of fixation time in males than in females. In both investigations, infants were first habituated and then tested for dishabituation in the same environment. Therefore, by the time the test with novel stimuli occurred, the environment was relatively familiar. Meyers and Cantor (1967) used a similar procedure and reported recovery of heart rate deceleration to a novel stimulus. They too were testing in a familiar environment and found the recovery only in males. McCall and Kagan (1970) also investigated habituation and dishabituation in the same environment and reported recovery of fixation time in both males and females. However, they did find sex differences in their heart rate deceleration data, and again only the boys exhibited recovery. In all of these examples, testing in a familiar environment led to more consistent recovery in male than in female infants.

The one investigation demonstrating greater recovery in females was reported by McCall and Kagan (1967). In this study, infants were familiarized with a stimulus in their home and were brought into a novel environment for the test. As noted previously, females did but males did not respond differentially to the novel and familiar test stimuli.

The pattern of results that emerges is that beyond 2 months of age, male infants display a more consistent preference for novelty when in a familiar environment but female infants prefer novelty more consistently
when in a novel environment. An additional factor which may interact with this pattern is the duration of exposure to the familiar stimulus. Although the studies in which only males showed recovery involved both long-term exposures of the familiarized stimulus in the infants’ homes and short-term exposures in a laboratory, the two investigations so far in which only females displayed recovery involved long-term home exposures, but no laboratory exposures.

Another pattern emerging from recent habituation data may help to explain why infants who exhibit recovery to novel stimuli sometimes habituate to the familiar stimulus and sometimes do not. Experiments demonstrating reasonably clear cases of habituation (e.g., Cohen et al., 1970; Pancratz & Cohen, 1970; Saayman et al., 1964) have tended to use simple geometric forms. On the other hand, those revealing little habituation or habituation in only a few of their infants (e.g., McCall & Kagan, 1970; Meyers & Cantor, 1967) have used more complex photographs or three-dimensional stimuli.

A few investigations have examined directly this potential interaction between rate of habituation and level of stimulus complexity. Cohen (1969a) attempted to habituate fixation time in different groups of infants to a flashing light which either remained stationary or moved among 4, 8, or 16 positions in a light matrix. While response decrements were found for all groups, no reliable difference in rate of decrement was obtained. However, a second experiment by Cohen provided some evidence that when two lights were simultaneously flashed, the rate of habituation is inversely related to overall amount of movement.

Ames (1966) and Caron and Caron (1968, 1969) have reported that habituation of infant visual fixation time is also more rapid to simple stimuli when checkerboard patterns are presented. In the Ames study, 5 1/2-week-old infants habituated more rapidly to a 2 X 2 than to an 8 X 8 checkerboard, while 11-week-old infants habituated more to an 8 X 8 than to a 24 X 24 checkerboard. Caron and Caron (1968) exposed 3 1/2 month olds to a 2 X 2, a 12 X 12, and a 24 X 24 checkerboard and obtained similar results—more rapid habituation, the simpler the pattern.

At the same time these experiments are demonstrating more rapid response decrements to simple stimuli, they are also demonstrating that the decrements are instances of habituation rather than fatigue or adaptation. If the infants were only tiring in the testing chamber, the response decrements to simple and complex stimuli would be equivalent. In order to maintain that either receptor adaptation or effector fatigue is responsible for the decrement, one must argue that such fatigue or adaptation accumulates more rapidly to simple patterns than to complex ones.
This argument, while not disproved, seems rather unlikely, particularly when the checkerboard patterns used have equal areas of black and white.

In conclusion, evidence now exists that the response of infants three and four months of age and older (and perhaps even as young as 5½ weeks) will habituate to repeated visual stimulation. The habituated response can also be elicited by a novel stimulus. Furthermore, most evidence indicates that the more novel the stimulus, the greater the response. In addition, such preference for a novel over a familiar stimulus may occur in the absence of prior habituation to the familiar stimulus, and as early as 2 months of age. Finally, the rate of habituation also appears to depend upon the age and sex of the infant and the complexity of the repeatedly exposed visual stimulation.

C. Habituation to Olfactory Stimulation

There appear to be only four good studies of habituation to stimulation other than visual or auditory. Engen, Lipsitt, and Kaye (1963) in one experiment compared the responses of neonates to acetic acid and phenylethyl alcohol, and in a second experiment compared responses to anise oil and asafetida. These stimuli differ presumably in odor and also in the degree to which they were irritants as opposed to "pure" olfactory stimuli. Respiration, bodily movement, and heart rate were recorded. The dependent variable was "... a judgment of whether or not any or all of the polygraph tracings during stimulus and control trials were larger than those observed for the 10-second interval immediately preceding the trial [p. 74]." The response to acetic acid was significantly larger than the response to alcohol, which was relatively low. Neither response declined over 10 trials (see Fig. 6). With anise oil and asafetida there was

![Fig. 6. Percentage of responses as a function of trials (from Engen et al., 1963).](image-url)
both a significant response to each, and a significant decline in response over trials. A significant order effect was also obtained. When asafetida was presented first, subsequent responses to anise oil were depressed significantly (see Fig. 7). In this second experiment, the second test series was followed by two presentations of the first test stimuli. A reasonably large response was obtained in both groups, but whether this should be called dishabituation or spontaneous recovery is debatable.

It is not clear why there was no decrement in responding to acetic acid or phenylethyl alcohol over trials. Although the failure to find habituation to acetic acid might be explained by the fact it is a very strong odorant that also stimulates the trigeminal nerves, phenylethyl alcohol proved to be a very weak stimulus and therefore should have shown habituation much like that obtained for anise oil in the second experiment.

Because their concern that the results of the two studies cited above might be accounted for by receptor adaptation rather than habituation, Engen and Lipsitt (1965) ran two additional studies in which presentations of a compound olfactory stimulus were followed by presentations of only a single component of the compound.

In these studies the odorants were anise oil, asafetida, amyl acetate, heptanol, a mixture of anise oil and asafetida, and a mixture of amyl

![Graph](image-url)
acetate and heptanol. In the first study a 50:50 mixture of anise oil and asafetida was used. Habituation was obtained over 10 trials, but while the response could then be reelicited by asafetida alone, it could not be reelicited by anise oil alone. This is not surprising considering that, in the earlier experiment, only a very weak response was obtained to anise oil when the anise oil series followed the asafetida series (see Fig. 7). In order to increase the likelihood that both stimuli would elicit the response following habituation to the combined odorants, a second experiment was conducted in which the combination of amyl acetate and heptanol was balanced such that the two component odors presented alone were approximately equally dissimilar to the combined odors.

This experiment conclusively demonstrated that a response could be obtained with a component cue following habituation to the compound. This finding could not be accounted for readily in terms of receptor adaptation. Thus, this experiment provides substantial support for calling the observed response decrement habituation. These four experiments also are among the few that show habituation of response in the neonate. It is important to note, however, that they are dealing with the arousal of a sleeping infant, the one condition where habituation of a defensive reflex does appear to occur (cf. Lewis et al., 1967).

III. Summary and Conclusions

A chapter on habituation in infants could not have been written a decade ago. There was too little evidence available. Bridger and Bartoshuk in the early 1960s were the first American investigators to explore systematically habituation in human infants, and since that time the amount of information on infant habituation has expanded considerably. By now we know that habituation is not readily obtained in the neonate. A possible exception to that statement is the case of olfactory stimulation, but perhaps habituation is common to any situation involving observations of arousal from sleep rather than the more specific components of orienting behavior. By 2 or 3 months of age, however, habituation of orienting behavior is clearly observable in a variety of modalities.

Several factors might underlie the general failure to obtain clear evidence for habituation in very young infants. Investigations of habituation to auditory stimulation have typically measured heart rate. Developmental changes in the nature of the heart rate response may account, in part at least, for the discrepancies in findings of response habituation at different ages. Before approximately 2 months of age, the usual heart rate response to a novel auditory stimulus is acceleration, while beyond 2 months it is deceleration (Graham & Clifton, 1966). If, as Graham...
and Clifton suggested, heart rate acceleration is part of the defensive reflex, one might not expect very young infants to display heart rate habituation. Moreover, evidence for habituation is generally obscured, and measurement is made difficult by the instability in the state of arousal of the infants. It also may be that the sensory analyzers of infants are not sufficiently developed to perceive the input, but it is more likely that, although the stimulation can be perceived, it is not stored and thus does not affect subsequent responses. Or it may be that the information can be both perceived and stored, but the responses that are being observed do not habituate. Other techniques, such as the use of conjugate reinforcement with the sucking operant (Siqueland, 1969), may lead to less equivocal results with infants under 2 months. Such a response obviously does not involve a defensive reflex.

Beyond 2 months of age the story is quite different. Not only are decrements obtained in a variety of responses, but also it is possible to evaluate the extent to which the other eight parametric characteristics of habituation as described by Thompson and Spencer pertain to these response decrements. For example, habituation has been shown to generalize to other similar stimuli, as Thompson and Spencer suggested, yet there are limits on that generalization. They also proposed that the rate of habituation should be influenced by both rate of stimulus presentation and the strength of stimulation. There is some evidence that the more rapid the rate of stimulus presentation the more rapid the habituation, but it is not sufficient to be compelling. The data on the effects of strength of stimulation are also equivocal. If by "strength" one means only intensity of stimulation, then there is no information on infants.

If the definition of "strength" includes complexity of stimulation as well as intensity, then considerable evidence is available. Several studies have demonstrated that the more complex the stimulation, the less rapid the habituation. The possibility of spontaneous recovery has also been explored by several investigators, i.e., the familiarized stimulus has been withheld for a period of time and then presented again. No convincing evidence of spontaneous recovery has been found, however.

Three of Thompson and Spencer's parametric characteristics of habituation remain unexplored. No one as yet has investigated the possibility that the effects of habituation might proceed beyond asymptotic response levels, nor has anyone attempted to find either potentiation of habituation or habituation of dishabituation.

Thus, in spite of the considerable number of studies cited, much more parametric information regarding habituation is needed. It remains difficult to make precise statements regarding optimal exposure times and intertrial intervals for any age, stimulus, or response. It is quite likely that such data might help to reveal important distinctions between
habituation and other response decrement phenomena, as well as to elucidate differences among such concepts as recovery, sensitization, and dishabituation.

The relative success of habituation research with infants at 3 months of age or more is encouraging. It is obvious that experimenters are finding ways of gaining access to a population that for the most part had been considered inaccessible. As researchers learn to provide more stable conditions and devise more reliable measures for this age group, they shall be more able to establish the relations among different classes of stimulation and different response measures. Such research will aid in separating alerting responses from attending and processing responses (Cohen, 1969b). This should prove very important. There must be a rather vast difference between the habituation of the child's eye fixations when presented with a checkerboard with 48 squares and the habituation of leg flexion to faradic stimulation; or general arousal to an unpleasant odor, but at this time no distinction is made.

Perhaps it is inevitable that most of the research reviewed has been directed primarily towards demonstrating infant habituation per se. The techniques currently available for producing habituation and recovery, however, are beginning to be used to investigate other phenomena. Lewis (1967) has probably done more than anybody to study habituation over a relatively wide age range and to assess the relationship between habituation rate and age. There is also research that suggests that rate of habituation may serve an early diagnostic role, at least with rather severe neurological disorders (Eisenberg et al., 1966), that it may mark interesting changes in normal neurological development (Hatton & Graham, 1969), and that rate of habituation may be predictive of other aspects of behavior as well (Lewis, 1967).

Habituation and recovery can also provide useful tools for investigating information processing ability of infants and memory or storage capacity. As Sokolov (1963) and Lewis (1967) have pointed out, habituation must involve some type of retention mechanism. The nature of this mechanism, however, and how it develops with age are almost totally unknown. Only a few studies have attempted to assess with sufficient precision the kind of environmental information that is assimilated and retained by young infants (Cohen et al., 1970; Moffitt, 1968). Investigations of how long and under what conditions this information will be retained are also beginning to appear in the literature (Pancratz & Cohen, 1970).

With more research of this nature, habituation, like learning, may come to take an important place in psychology both as a manifestation of behavioral plasticity as well as a technique for revealing information regarding significant behavioral processes.
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