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Studies on learning in infants show that in infancy every month of life represents a new level of learning. The functional state of the central nervous system can be influenced by physiological factors which cause fluctuating changes in functions important for learning. Once a stimulus becomes a conditioned signal, it acquires strong power in influencing an infant's behavior. More is known about the relative value of different reinforcing unconditioned stimuli than about the relative value of conditioning stimuli. Further research is needed on the development of central mechanisms responsible for the processing of sensory input and for the structuring and integration of information. It is likely that preverbal forms of information interaction and integration will become the center of increased research attention. In studies of postnatal development, the physiological and psychological disciplines merge. (MS)

# LEARNING IN INFANTS

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During the past years, psychologists as well as pediatricians, neurophysiologists, and other scientists, have paid more and more attention to the development of behavior, and particularly to learning in early infancy. This comes partly from a general acceptance of the assumption that the earliest experiences and events can play a very important role in further development of mental functions, and that we can better understand the structure of complicated functions if we study their initial postnatal development. Partly, of course, it is connected with the ease with which human subjects can be obtained in the first year of life for psychological studies, and with the development of increasingly precise methods of observation and experimentation in immature, fragile organisms.

As new ways have been found to study infant behavior, new opportunities appeared, encouraging the exploration of the difficult problem of applying fresh and attractive aspects of learning theory to the period of early postnatal development. But so far, most published studies remain at a basic descriptive level. (Comprehensive surveys were recently published by Rheingold and Stanley, and by Lipsitt.) Obviously, much more descriptive work is still to be done before more general conclusions about the early development of learning can be expected. Nevertheless, since this Learning Advisory Group is, I believe, supposed to pay more attention to the prospective part

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of the pathways of research in early learning, it may be useful, at least, to touch on some general theoretical problems of learning in infants, and draw more attention to some peculiarities of infancy, important from the point of view of theoretical models of learning.

If we take into consideration the most generally accepted definitions and theories of learning, whether of the empirical type dealing with physically observable events, or of the theoretical type trying to postulate the essential conditions of learning processes, we can see that they examine learning under more or less stable conditions. Looking for the essential laws of learning, they exclude adaptational, physiological, and particularly maturational variables. Experienced students investigating learning problems would not be surprised to find certain discrepancies between general normative laws in learning theories and the concrete course of learning in individuals. But working with infants, one often feels that at this stage of development, learning is controlled by quite a different category of laws.

This becomes more understandable when we realize that, during infancy, all those adaptational, physiological and maturational variables excluded from consideration in most of the general models of learning, play their most important role at this relative age period. Their power is higher the closer we come to the moment of birth in our experimental subjects. Thus, for example, if we want to apply the Bergmann and Spence model, we have to bear in mind first that the intervening variables must always be modified according to the level of maturation; and secondly, that due to the physiological and adaptational factors, the intervening variables are never as stable as in adults, even during one experimental session.

In no other period of postnatal life are both somatic and functional development as rapid as during infancy. Within the first 4 - 5 months, the weight of an infant redoubles, and this is necessarily connected with a very high caloric intake and rate of metabolism. Functional development of sensory organs, particularly telereceptors, sensory-motor coordination, locomotor functions and other motor skills, as well as increasing contacts with social environment, represent such dramatic changes in the input of information and in potential abilities to respond to the input that, without any overexaggeration, we can assume different phases of stimulus-response interaction for individual months of life.

Some of these dramatic changes require gradual adjustment to the new conditions, and it is not difficult to imagine that such an adjustment can itself cause polyphasic changes in behavior. The most complex process of adjustment is undoubtedly connected with the sudden change of environment at the moment of birth. The neonate, so far protected by the aquatic intrauterine medium, provided with adequate nutrition and oxygen by the maternal organism, and exposed to only a limited amount of environmental stimulation suddenly starts a new, completely different way of independent life requiring complete changes in blood circulation, respiration, thermoregulation, nutrition, etc. He must also become adjusted to a new and changing microbial environment. Weaning, dentition, locomotion can serve as other examples.

A question arises as to the effect such maturational and adaptational changes can have on the development of learning. Since age can be considered the common denominator of all individual kinds of developmental change, it is a question of the influence of age upon learning. There are very few studies which analyze in detail the dependence of learning upon age during early postnatal life. In our own study (Janoš and Papoušek) using the methods of conditioned eye-blinking and conditioned head-turning, we showed that the dependence of the rate of conditioning upon age is of an exponential character, with a rapid increase in the rate of conditioning during the first half year of life. Comparing different age groups we found that an age difference of one month is enough to demonstrate statistically significant differences in the rate of conditioning. This, in other words, really means that every month of life represents a new level of learning.

Quite apart from factors causing a constant developmental trend in learning abilities, the functional state of the central nervous system can be influenced by physiological factors causing fluctuating changes in functions that are important from the point of view of learning. Such changes result in many increases and decreases of excitability of different types and origins.

The most important and best known changes of excitability are those connected with the changes in general state, usually known as sleep, waking, and transitional states between sleep and waking. Although the gross changes in the general state are relatively easily observable, serious attempts have been started to analyze more precisely their objective physiological parameters, using electromyograms from different muscle groups, electroencephalogram, electrocardiogram or pneumogram (Prechtl). It is particularly important to distinguish the transitional states which are relatively frequent in infants, but less easily detectable. The periodicity of individual states in newborns and infants has been classified and studied by Aserinsky & Kleitman, Beintema, Dittrichova, Escalona, Irwin, Parmelee, Wolf and others. Both the distribution and duration of different states show typical peculiarities in newborns, and a distinct developmental change in infants. Neonates, according to Beintema & Prechtl, spend 70 - 83% of their time in states of sleep or transitional sleep, but periods of sleep or of waking are very short (36 - 362 seconds) and very frequent. Gradually, during the first half year of life, the time spent in transitional states decreases, and periods of deep sleep and active waking become longer (Dittrichova).

Within the periods of waking, secondary microwaves can be observed which appear as momentary decreases or increases in excitability, and which are much less well understood and not always evaluated. These oscillations are not intensive enough to meet the criteria for a change in general state, but still can cause a decrease in response or failure to respond to a given stimulus. In conditioned responses, e.g. in conditioned head movements as studied by the author, changes in latency and intensity of CR together with changes in breathing and general motor activity give sufficient evidence of such microwaves of increased excitation or deeper inhibition. According to the author's opinion, which is, of course, limited to a given experimental situation, these oscillations do not seem to be regular rhythmic phenomena, but rather appear as a function of the conditioned stimulation itself. In many cases they illustrate perfectly the Pavlovian concept of the mutual interaction of excitatory and inhibitory processes, their induction, irradiation or concentration. During the initial phase of conditioning in neonates, as observed by the author, the interaction between excitation and inhibition can cause the inability of neonates to group consecutive correct conditioned responses.

It is not very hard for an experienced experimenter to observe these oscillations in general state (e.g., changes in arousal level, attention, or momentary excitatory potential). But it is indeed difficult to find easily measurable physiological parameters of these changes. In a recent discussion with Jerome Kagan, we thought of attention as a profile of thresholds at the level of unconditioned responses which could be characterized by some representative cardinal thresholds. As I realized later, the changes in general state, as they were studied in Pavlovian laboratories, can exert an even greater influence over conditioned activity than over unconditioned reflexes. Perhaps further progress in electrophysiology will bring some solution to this difficult open problem.

Two more aspects of the problem of thresholds should be mentioned. The first one is related to the limits within which the intensity of a response can be a linear function of the intensity of the stimulus.

Below these limits, the stimulus becomes subliminal and stops eliciting responses under normal conditions, while above them, the stimulus becomes supraliminal and elicits qualitatively different responses or causes the so-called supraliminal inhibition. These limits can differ substantially from the adult thresholds so that stimuli of normal intensity (from the point of view of adult organisms) can easily act as subliminal or supraliminal stimuli in infants.

The second aspect is related to the content and meaning of stimuli, based upon the preceding experiences the organism had with them. At the beginning of life, the content of external stimuli is necessarily poor, and unlike the situation with adults, it is relatively easy to find stimuli which have not yet been associated with any infant's experiences outside the experimental situation. On the other hand, it is known that once a stimulus becomes a conditioned signal, it may acquire a very strong power in influencing an infant's behavior. It can even shade the effect of reality, of unconditioned stimuli.

The question of a genetically determined sensitivity to certain qualities of stimuli is interesting, but is not yet sufficiently studied in humans. This question was raised by ethologists and comparative physiologists who observed that, in some species, young infants are selectively sensitive to those stimuli which are to play an important role in their respective way of life. In young foxes, for example, it is very difficult to establish conditioned reflexes to tones, unless the tones are similar to the squeaking of mice. In young hares, sounds similar to the crackling of footsteps in dry grass are most easily used in the conditioning process. Some hierarchy in different kinds of external stimuli in human infants would not be surprising, but so far we know more about the relative value of different reinforcing unconditioned stimuli, such as human voice or other patterns of social contacts (Brackbill, Gewirtz, Koch, Rheingold, et al) than about the relative value of conditioning stimuli.

In addition, little attention has been paid to the development of the central mechanisms responsible for the processing of sensory input and for the structuring and integration of information. These are certainly as involved in the process of development of learning abilities as the developmental changes in sensory organs, afferent systems or effectors. This lack of attention may be the result of limited methodological possibilities, the unfeasibility of verbal communication with infants and a lack of appropriate theoretical models.

We must consider the general question of whether these problems can be studied at the preverbal stage of development. I personally believe that the preverbal forms of informational interaction and integration will soon become the center of increased attention. This belief is based upon several stimulating facts.

First, finer methods used in the past few years to study perception have shown evidence of elementary, obviously inborn, forms of internal structuring in perception already active in newborns (Hershenson, Kessen). Second, our own studies of conditioned discrimination have led us to observe the formation of what might be called elementary concepts in problem solving in infants at the age of 4 - 6 months. Third, neurophysiologists have been paying increased attention to the problem of the orienting reflex, spontaneous exploratory behavior, and intrinsic motivation. They have discovered evidence of efferent impulses from the brain feedback itself which assumes the presence of some central regulation of input coming from receptors and of motor output from the brain (Scherrer, Jouven). These findings were of unusual importance for the conceptualization of units in the CNS which could bring an answer to the question of instigators in motivation. Miller, Galanter and Pribram expanded it into the concept of Test-Operation- Test-Exit units and worked out a theory of the instigatory role of incongruity between information input and given standards. Generalizing this principle from the level of energy to the levels of information and control, they designed a hypothetical model of the physiological background of standards guiding human behavior at the level of plans and ideas. This concept was used in a broader behavioral application by J. McV. Hunt.

Thus, it seems that at present, on the basis of solid experimental data, an interesting theory has emerged that can initiate new interest in studying the development of internal structuring and integration.

Study of the aforementioned developmental changes in the highest nervous system functions is also necessarily connected with the problem of individual differences in the development of learning. Scientists commonly tend to look for normative mean values, but luckily life tends to produce individual deviations from such means. Pavlov's interest in human typology initiated an interest in individual differences in conditioning. Krasnogorski, Ivanov-Smolenski, Volokhov and others attempted to classify types of the nervous system on the basis of qualitative differences in the processes of excitation and inhibition, as the differences present themselves in the course of different conditioning procedures.

The study of individual differences has, of course, much broader significance and can help in analyzing the role of different environmental factors in development of learning capacities. In the form of longitudinal studies, the study of individual differences can help in evaluating the predictive meaning of early differences in learning abilities and in estimating the corrective role of educational measures, for instance. As we saw in our studies of individual differences in conditioning abilities, these differences can have various dimensions. Infants can differ in the directions of development on one hand, and in the rate at which they develop in the same direction on the other hand. A lack of methods for distinguishing these different dimensions represents another open problem in investigating the early development of learning.

This brief outline of some more general problems of learning in infancy has not aimed at a complete list of problems or at a detailed discussion of them. It may seem to be oriented more physiologically than psychologically, but as far as the beginning of postnatal development is concerned, the differences between both disciplines merge and, as a matter of fact, team work with good cross-disciplinary cooperation seems to be the method of choice in this direction particularly.