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ABSTRACT

This essay concerns the development of cognitive and perceptual skills in children from birth to the age of nine. It surveys issues, beliefs, and information about perceptual and cognitive procedures. It discusses the issues of nature-nurture, maturation-learning, continuity-discontinuity, and critical periods. It describes the development of specific cognitive skills including conditioning; perceptual and discrimination learning; transfer; verbal learning and memory; and concept learning. The essay concludes with some generalizations. Massive changes occur in the child's intellectual capacities from birth to nine years. Children of the same age differ in learning capacities and the child's capacity varies with the way a task is presented. Children learn from systematic experience from birth onward, and many tasks routinely regarded as relatively simple by adults require capabilities that many children do not achieve until late in the age range. (DG)

Cognitive and Perceptual Development in Children[1]

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This essay concerns the development of cognitive and perceptual skills in children from birth to approximately age nine. Accordingly, we will survey some of the issues, beliefs, and information that claim the attention of developmental psychologists who work on perceptual and cognitive processes. The survey will be selective rather than comprehensive because of its purpose: to be of use in dealing with issues surrounding the education of young, handicapped children. Within this selection we will begin with a consideration of relatively general issues, move next to a review of developmental changes in more specific categories of behavior, and conclude with a brief summary.

General Issues in Cognitive and Perceptual Development

In this section we will be concerned with four major issues on which developmental psychologists divide. These issues represent current versions of long-standing disputes: nature-nurture, maturation-learning, continuity-discontinuity, and critical periods. The issues overlap to a considerable degree, but there is enough distinctiveness to warrant separate treatment.

Nature-Nurture

One of the intriguing aspects of the nature-nurture issue is that it lends itself to misstatement. Such misstatement is exemplified in a question like, "Is intelligence determined by heredity or by environment?" It is also exemplified by the question, "Is development caused by heredity or environment?"

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The first question is misleading because it implies that some portion of a trait, in an individual, is determined by either heredity or environment. In fact, the issue is to determine the proportion of variability in a trait, across individuals, in the same population, under a specified range of environmental conditions, that can be attributed to genetic variability in the population and what proportion can be attributed to variability across the environment in which the population is found. The second question is misleading for a very different reason--it is not germane to the issue. Instead this question pertains to the second issue to be discussed here, namely, that of specifying the mechanisms responsible for development in general, not differences in development across persons.

Given an appropriate formulation of the nature-nurture issue, it is possible to specify the particular aspects of it that are in dispute and those that elicit substantial consensus. To begin with a relatively conflict-free aspect, there is little disagreement with the proposition that within well-defined populations (e.g., U.S. citizens of third-generation, northern U.S. white parentage) variability in behavioral traits, such as I.Q. is partly attributable to corresponding genetic variability. Instances of agreement on this point are easy to come by. One such is the fact that within populations, some groups of persons are designated as familially retarded.

It is important to emphasize that even in cases such as that of mental retardation, an explanation of variability in IQ in terms of corresponding genetic variability does not imply that the performances used to index the trait are fixed and impervious to improvement. Obviously, persons who are called retarded learn a wide variety of skills and the levels of performance they achieve depend importantly on learning conditions. Thus, the fact that differences in a trait are substantially attributable to genetic variability does not necessarily imply that there is a fixed ceiling on performance.

Among the unresolved topics surrounding the nature-nurture issue are two that have provoked substantial controversy. One of these is largely a result of the present paucity of relevant research. That is to say, the heritability (proportion of behavioral variation attributable to corresponding genetic variation) of many, many behavioral traits is almost completely unknown, principally because the necessary investigations have not been made. The case of intelligence test performance is exceptional in that a variety of methods have been applied to determine its heritability within populations. By comparison, virtually no effort has been expended to estimate the heritability of concept learning or verbal memory or problem solving behavior, etc. Thus, there are many gaps in our knowledge of the heritability of behavioral traits but these gaps can, in time, be closed since there is some considerable consensus about the methods appropriate for doing so.

In contrast, the topic in the nature-nurture domain that arouses the most intense controversy cannot be managed in such a straightforward manner. In a series of recent publications, Jensen (e.g., 1969) has suggested the hypothesis that differences <u>between</u> populations, as well as differences <u>within</u> populations are attributable to corresponding genetic differences. This hypothesis has stirred dispute at a variety of levels; there is little consensus about the kinds of methods appropriate for evaluating the hypothesis; and, there is great disagreement about the content of the hypothesis. For example, the hypothesis implies that observed IQ differences between racial populations, socioeconomic populations, and other subcultural populations, may be attributable to corresponding genetic variability between the populations. At present, it appears there is little chance that the problems raised by this hypothesis will be readily resolved.

What are the implications of the nature-nurture issue for those working with children who, for one reason or another, are educationally handicapped? One implications is clear, namely, that variability across persons in performance on perceptual or intellectual tasks is to be expected. Apart from this, little else is compelling at the present time. Until and unless the many unresolved disputes are clarified, the fact of individual differences may best be incorporated into intervention attempts by providing a variety of avenues for the achievement of any given set of objectives.

Maturation-Learning

On most cognitive or perceptual tasks that have been administered to children, the result is: the older the child, the higher the level of his performance. The question is how is such developmental change to be explained? One alternative is to postulate a psychological counterpart to physical growth processes, maturation, and to attribute increasing competence to more advanced states of growth. Another alternative is to account for all changes toward higher and higher levels of intellectual and perceptual competence in terms of the processes of learning, transfer and memory. Even though neither of these alternatives is at present espoused in pure form by any substantial number of psychologists, the different emphases they suggest are realized in two of the most lively current approaches to understanding developmental change.

When the emphases of these two approaches are stated generally, the difference between them appears quite dramatic. Nevertheless, it is not a simple matter to specify the difference in detail and to identify it with particular implications for practice. For the purpose of discussion the positions may be identified with illustrative exponents: Piaget on the one hand, and Gagné on the other. In Gagné's view (1970), the difference between the position he has promulgated as the cumulative learning model and that expounded by Piaget is a striking one with regard to implications for educational practice:

> If growth is the dominant theme, educational events are designed to wait until the child is ready for learning. In contrast, if learning is a dominant emphasis, the years are to be filled with systematically planned events of learning, and there is virtually no waiting except for the time required to bring about such changes. Gagné, 1968 (p. 178).

Ostensibly, this difference is a profound one. But consider an example. Suppose for some reason the performance of accurately judging the numerical equivalence of sets of crayons, however they are arranged on a table, is a critical objective of schooling for five-year olds. Whether one were a Gagnéan or a Piagetian, he would agree that this specific objective is attainable and that its attainment could be promoted by arranging a set of environmental experiences appropriately. Adherents of the two positions might well disagree about exactly what the set of most appropriate experiences would be, but this could be settled by empirical test.

Thus we still face the question, How do the opposing positions differ? One answer is that they differ in their interpretation of the meaning of attaining competence on a particular specific task. Consider the case where learning conditions are systematically arranged to promote the attainment of a particular task performance by a five year old who would otherwise not have attained the performance until age six or seven. In Gagné's view such a performance has the same significance as it would have were it attained by the child in the natural course of events. For Piaget, this is not the case; instead, precocious attainment is regarded as being spurious in the sense that it signifies only the mastery of a particular behavior sequence and not of the underlying competence necessary for successfully attacking tasks of this kind. Thus, a Piagetian might well expect that precocious achievement, made possible through educational intervention, would have little value, or transfer, beyond the particular learning accomplished. It would certainly not have the same significance as attaining the competence through the normal processes of development. In contrast, a Gagnéan would hold that the transferability of learning engineered through intervention would be as great as that of learning that occurred in a normal setting, since the processes involved in both cases are the same--they differ only in that the one (intervention) is more efficient and sure than the other.

At present, this version of the maturation-learning issue remains unresolved. Obviously, however, it has critical implications for educational practice and especially for educational practice with handicapped children. The question is whether or not it is beneficial, in the long run, to design programs that will accelerate the attainment of intellectual performance objectives in young children or to let the overriding processes of development take their course.

Continuity-Discontinuity

The continuity-discontinuity issue turns on the decision whether or not to adopt a stage conception of the course of development. Examples of such a conception may be found in Piagetian theory and in psychoanalytic theory. Since both of these theories give considerable emphasis to maturation as a major mechanism of development, it is tempting to identify a stage conception with a maturational position and a cumulative conception with positions having a learning emphasis. By and large, this would be an accurate interpretation but it need not be so. For example, a developmental theory having a learning emphasis might well include stage conceptions that are defined in terms of the normative kinds of environments to which children of various ages are exposed. It might be postulated that the first stage is marked off by the very early part of life, infancy, when the person's environment consists largely of his mother, followed by a stage defined by the immediate family, followed again by a stage characterized by the increasing dominance of the peer environment. Thus, a decision in favor of a developmental theory that emphasizes learning does not necessarily preclude the adoption of stage conception of developmental progression.

One advantage of a stage conception is that it provides a summary of the child's capabilities as he matures, presumably allowing the observer, or the educator, to make accurate predictions of what the child can and cannot do on specific tasks so long as he knows what stage the child has attained. To take a Piagetian example, only if a child has attained the stage of concrete operations will he be able to learn successfully to conserve quantities, like number, substance, volume, etc., when their appearance is transformed. Accordingly, it would be fruitless to expend educational resources, and the child's resources, attempting to engage him in the learning of school subjects that require for their accomplishment the underlying competence described as concrete operations. Thus, the implication here is that in order for educational experiences to be productive, they should be designed to match the child's developmental level, not to advance his developmental level.

In contrast, a continuity model of human development, like Gagné's cumulative learning model, has the disadvantage that it does not provide a general specification of the child's competence from which particular predictions can be made about what he will be able to learn. This is because the model explicitly assumes that he can learn virtually anything, at any age (apart from the limits imposed by physical growth) so long as he has accomplished the necessary prerequisite learning. The implication here is that the educator must know what the child has previously learned not what stage he is at.

Another distinction between stage and continuity theories deserves special emphasis, namely, the assertion in stage theories that the character of cognitive processes at ascending developmental levels is qualitatively different. In a continuity theory like Gagné's, the older child is regarded as having greater intellectual power than the younger because he has learned more and therefore possesses more relevant past learning that can be transferred to new tasks. It is this capacity for transfer that makes the older child appear to be startlingly more proficient than the younger. In the continuity position, this explanation is extended to other kinds of intellectual differences so that older children, high-IQ children, dominant-culture children, and so on, are distinguished from younger children, low-IQ children, variant-culture children, in terms of what they have learned previously. A stage conception of development, however, lends itself to interpretations of such individual differences in terms of qualitative differences in the character of the processes that typify the learning and thinking of various types of children at equivalent ages.

Let us conclude this section with an example of the implications of a stage position in comparison with a continuity position. Suppose one objective of schooling for second-grade children was that they should be able to design experiments to test predictions about phenomena that involve the relationships among three or four variables. An illustration would be the design of tests for hypotheses about why some objects float in water while others do not. This is, of course, a very demanding objective for second-grade children. Accordingly, whether one adopted a Gagnéan position or a Piagetian position, he would expect that accomplishing the objective would be very difficult indeed. There are differences, however, one being that a Piagetian position would lead to the expectation that the objective could really not be attained in a satisfactory way until the children were much more advanced developmentally. To be more specific, they would have to have attained the stage of formal operations before instruction could be effective in promoting the capability of designing experiments. The Gagnéan position, in contrast, would be that some children in the group might already have met the objective, if they had completed the necessary prerequiste learning, and that the other children could meet it if the instructional conditions were properly designed and the necessary prerequisite learning were accomplished. Thus, a continuity position tells you little about what to expect of the child, until you have assessed in considerable detail the previous learning he has accomplished.

Critical Periods

The decision whether or not to incorporate the postulate of critical periods into a conception of the mechanisms of human cognitive development has far-reaching implications. Roughly speaking, a critical period is a span of time during which an organism must have experiences of a particular kind if he is ever to acquire certain later skills. Such periods are usually located very early in the organism's life span. The reality of the critical period mechanism has been relatively well-established for some particular forms of behavior in some species. If it is valid for human development, then of course, it becomes crucial to insure that children, at very young ages, are provided with these necessary prerequisite experiences. In a very influential book, Hunt (1961) provided support for this proposition, drawing on results of research studies on animal behavior. The possible reality of critical periods, thus, forms one of the compelling bases for recommending very early formal control over the learning environment.

Despite its crucial importance, however, there is, at present, no substantial evidence to support the belief that critical periods are involved in the mechanisms of human intellectual development (Thompson and Grusec, 1970). Indeed, some developmental psychologists interpret the available evidence in an opposite direction (e.g., Elkind, 1969) suggesting that early formal instruction may retard rather than facilitate later intellectual development. Furthermore, other evidence can be viewed as implying that the earlier the onset of formal schooling, the more negative the eventual attitudes toward school, especially among students from families of lower socioeconomic status (Rohwwer, 1971). Thus, for the moment, the implications of the notion of critical periods for educational design are negligible at best.

The Development of Specific Perceptual and Cognitive Skills

In one sense, a great amount of research has already been completed on the topic of the development of specific perceptual and cognitive skills. Yet, in another sense, the research has produced only a small amount of information that is directly useful at the level of designing specific instructional sequences for special groups of children. Nevertheless, in the amount of space available here, it will be impossible to provide an adequate account of the relevant information; for additional amplification on any of the topics mentioned, it may be especially profitable to consult two recent reference works, Mussen (1970) and Reese and Lipsitt (1970).

The remainder of this review will be organized in terms of the following kinds of specific skills: conditioning, perceptual and discrimination learning, transfer, verbal learning and memory, and, concept learning. In a crude sense, the ordering of these topics is from simpler to more complex intellectual skills, although those psychologists who do research on so-called simpler skills might dispute this vigorously.

Conditioning

We will follow here the common practice of distinguishing two major kinds of conditioning: classical and instrumental. The first refers to cases where a stimulus that initially has no power to evoke a response comes to do so by virtue of being repeatedly presented with a stimulus that already has the power to evoke that response. For example, a tone can come to elicit an eye-blink if it is repeatedly presented when a puff of air is blown at the eye. The procedure for producing instrumental learning differs in that the delivery of reinforcement immediately following a response is believed to control the response.

Recently, both of these forms of conditioning have been shown to occur in very young infants, as young as one or two days of age (Siqueland & Lipsitt, 1966). The response under investigation was that of head turning. It was demonstrated that repeated presentation of a buzzer along with tactile stimulation of the cheek resulted in head turning to the buzzer alone. Similarly, the frequency of head turning was increased by delivering a reinforcer, a sugar solution, after the response. Thus, the evidence gives strong support to the notion that both these forms of learning, classical and instrumental conditioning, are within the capability of the newborn.

Just as both forms of conditioning are available avenues of learning early in life, so they both persist into adulthood. With regard to classical conditioning, the evidence is not at all solid about developmental changes. There is some suggestion that the ease of conditioning increases from birth to about age four years, either levelling off or decreasing thereafter. The task ahead for investigators in this area is a difficult one since it is not clear whether those age differences that have been observed are due to capacity, motivation, or sensory thresholds.

Age trends that have been unearthed in studies of instrumental conditioning are also rather sparse. There is some evidence that so-called symbolic reinforcement (praise, tokens, etc.) is more effective in promoting learning the older the child, whereas material rewards are more effective with younger children. A similar effect has been reported for the classification factor of SES as well, but in neither case is the evidence sufficiently strong to compel belief. One developmental trend that does seem well-established is that related to the extent of generalization. The question is this: Once a child has learned, through reinforcement, to make a response to a particular stimulus, say a light of certain brightness, how different in brightness must the light be before it will no longer elicit the response? A pronounced relationship with age has been found, such that the older the child across the range four to twelve years, the less the extent of generalization. Thus, great care must be taken with younger children to insure that the response they learn does not generalize to stimuli for which it is inappropriate.

Perceptual and Discrimination Learning

Like most other intellectual functions, perceptual proficiency generally increases with age. Proficiency in this domain is indexed in a variety of ways, including prominently tasks that require the following: identifying a previously presented stimulus in an array of other stimuli; recognizing that changes either have or have not been made in stimuli on successive presentations. These indexes have been used in research on perception in several different modalities: visual, auditory, tactile, etc. The results of an enormous number of studies make fascinating, though very complex, reading.

Early experience (i.e., in infancy) has been shown to have some effect on later perceptual proficiency. A few studies have shown that enriching the infant's visual field contributes to increased perceptual activity. In contrast to the enrichment studies, another method for studying the effects of early experience is that of deprivation. Most such work has been conducted with animals but a small number of studies has been carried out with human beings. It has been shown, for example, that young children who have been blind from birth are less proficient in tactually perceiving and discriminating shapes or forms than sighted children. This result, however, has not been confirmed for the tactual discrimination of texture.

One interesting line of research has concerned the child's ability to detect changes in the orientation of forms on successive presentations. Two such transformations have received heavy emphasis: mirror-image, left-right, and mirror-image, up-down changes. In general, the results show that left-right discriminations are very difficult indeed for children up to age six, after which improvement is rapid. In contrast, children as young as three and one-half years are proficient at detecting up-down transformations. Two methods for improving the young child's ability to detect left-right transformations have been shown effective. The first is to present the stimuli simultaneously in a vertical array rather than side-by-side in a horizontal array. Similarly, the performance of kindergarten children on the left-right discrimination was measurably improved by a training procedure in which the children were required to move a lever in the same direction as the orientation of the stimulus as it was presented. Thus, learning a movement correlated with the orientation of a visual form improved performance. Such methods are, of course, relevant to the design of instruction to promote pre-reading skills.

Two other lines of research are especially relevant to the topic of perceptual learning as it relates to reading. The first of these revolves around a theoretical position in which the concept of distinctive features plays a prominent role. This position holds that improvement in perceptual proficiency occurs because of increasing sensitivity to those aspects of stimuli that distinguish among the several members of a set. For example, letters are a set of stimuli in which certain features (e.g., curve-straight, open-closed) are important for determining the identity of each member. Research using this approach has shown that young children, up to ages of approximately seven or eight, find the task of discriminating such stimuli especially difficult. One helpful procedure for younger children is that of presenting series of complex stimuli that have some components in common while allowing other components--those that are not distinctive features--to vary. The child's task then is to detect those complex configurations, e.g., four-letter words, that do and do not share the common elements or features.

Still another topic relevant to reading concerns the reputed trend that younger children are prone to attend to the whole rather than to the parts of a visual stimulus whereas older children focus on the parts as well. This is an important phenomenon, if valid, for the reason that it has been used to support the "look-say" approach to beginning reading. The problem is that the validity of the trend is in considerable doubt. Indeed, the truth seems more closely approximated by the assertion that younger children are less sensitive to perceptual features, whether they distinguish parts or wholes, than older children. Accordingly, those features of a complex stimulus, such as printed words, that are critical for learning, must be emphasized somehow when they are presented to young children, regardless whether the features are "parts" or "wholes."

Some recent research (cited in Reese & Lipsitt, 1970) seems to suggest that the increasing perceptual proficiency of children as they develop across the range of 3 to 7 years, is attributable to increasingly systematic scanning of visual stimuli. The younger children, as revealed by records of their eye movements, characteristically fail to scan the contours and parts of visual stimuli in a comprehensive way, focussing instead on only a few portions of the form presented. Older children virtually reproduce with their eye movements the figures presented.

A widely known age trend in the domain of perception provides a bridge to the second topic of this section, namely, discrimination learning. This trend concerns differences in dimensional preference. The most prominent example is illustrated in a task where the child is shown a target stimulus, a yellow circle, and asked to indicate which of two other stimuli, a yellow square or a blue circle, is most similar to the target. His choice is regarded as indicating a preference for either the form or color dimensions that describe the stimuli. Much of the available data indicates that there is a marked shift over the age range 3 to 8 years from color to form preference. The shift is so complete that the older children almost never make color choices. For young children, the ordering of dimensions from most to least preferred is: color, size, number, form; for older children it is: form, color, size, number. Among older children, it has also been found that deaf children prefer the color to the form dimension, whereas hearing children exhibit a preference for form. Despite the apparent regularities in dimensional preference reported here, some caution is warranted in drawing conclusions. This is because of recent work showing that the preferences can be shifted by varying the difficulty of the discrimination required.

Dimensional preferences lead into a summary of work on discrimination learning because the tasks used in this kind of research usually confront children with stimuli that differ on the familiar dimensions just discussed. Typically, the child is asked to learn which of two kinds of stimuli the experimenter has designated as correct and which he has designated as incorrect. The two classes may differ in any one or more of several ways. For example, "green" stimuli might be correct, whether they are circles or squares. Given such tasks, some investigators have found that the efficiency of performance depends on whether or not the critical dimension is one preferred by the child; if it is, he performs well, if not, he appears to learn very slowly.

Another factor that exerts pronounced effects on discrimination learning is whether or not the stimuli to be discriminated are presented successively or simultaneously. Simultaneous presentation substantially improves performance, presumably because the child can more readily compare the two stimuli and thus become sensitive to their distinctive features--the dimensions on which they do and do not differ.

Perhaps the most interesting age trend that has been observed in studies of discrimination learning is that proficiency seems to increase and then to decrease. For example, five year olds perform better than three year olds but they also perform better than seven and nine year olds,and so on to college age where performance is little better than for three year olds. One interpretation for this trend is that the older the person, the less likely he is to believe the experimenter's description of the task. Thus he spends inordinate amounts of time attempting to solve a problem when in fact, all he must do is learn a discrimination.

Transfer

One of the main purposes of transfer experiments in developmental research is to reveal what it is children learn in perceptual and discrimination learning tasks. For example, in one kind of transfer method, transposition, the child first learns to discriminate between two circles that differ in diameter. After he comes to consistently select the larger one, the two stimuli are changed so that the circle that was initially larger is now presented with another circle that is still larger. The question is, will the child continue to select the same circle he has been choosing or will he select the larger one? The first kind of outcome is interpreted as indicating the child has learned a simple connection between a particular stimulus and a response whereas the second is regarded as implying that he has learned a relationship--a kind of low-level concept.

A variety of experimental paradigms have been applied to the problem of determining the age at which children characteristically learn relationships, or concepts, rather than simple connections. Some of these are: discrimination shift, transposition, and, oddity problems. The results of many of these studies lend credence to the supposition that over the age range four to seven years, children shift from learning simple connections to learning concepts. Several different theories have been formulated to account for this shift but the problem is that conflicting empirical results have emerged, that is, some studies have found little evidence that the shift from associative to conceptual learning is a developmental phenomenon, concluding instead that it varies as a function of task conditions such as whether or not preferred dimensions are used. Nevertheless, at present, the predominant weight of evidence, from a variety of tasks, favors the notion that the way children learn undergoes marked changes during the four to seven year range.

One final point must be made about performance on discrimination learning and transfer tasks: when he is not given instructional assistance, the young child finds such tasks remarkably difficult. The tasks themselves are ostensibly very easy ones, at least to the adult eye. For example, suppose a child is confronted with a series of oddity problems. These consist of presenting three objects on each trial where two of the objects are identical and one is different. Since a new set of objects is presented on every trial, the child must learn to choose the odd object. In one such study only 10% of four year olds were able to master the task within 200 trials, whereas all of the sample of twelve year olds could do so. Thus, it seems warranted to conclude that young children, especially in the preschool and primary grade range, need substantial instructional assistance in order to learn even what it is they are supposed to learn.

Verbal Learning and Memory

Typically, studies of verbal learning in children use tasks that require the child to recite lists of words that bear only an arbitrary relation to one another. One such task, serial learning, entails learning the exact order in which a list of items is presented. Another task, perhaps the one most often used, is called paired-associates. Here the child is presented with a list of word pairs and asked to learn them in a way that he can remember the second member of each pair when presented with the first. These tasks and others like them have been used to investigate a variety of issues recently, some of which are relevant to our concerns here.

One such issue concerns the age at which children begin voluntarily, that is, in the absence of instructions to do so, to elaborate the materials presented for learning. For example, suppose a child is asked to learn the identity of a series of pictures of familiar objects by associating the picture with its position on a table. The question is, when do children begin to sub-vocally rehearse the verbal labels of the pictured objects in order to learn? In a series of studies, Flavell (1970) has conducted extensive analyses of this issue with the tentative result that this kind of simple activity emerges in the familiar four to seven year age range. Two more complex forms of mental activity believed to occur when adults learn lists of paired associates seem not to occur, in the absence of special prompting, until well beyond the age range with which we are concerned here. These activities may be described as verbal and pictorial, although the exact character of the internal processes involved has not been identified as yet. When asked to learn a noun pair such as fish-pipe, adults report thinking of a fish smoking a pipe, either in words or in images. There is little indication that these activities are characteristic of children's learning before the ages of 12 to 14 years.

Even though younger children appear not to engage in these more complex forms of elaborating verbal materials, many studies have shown that the efficiency of their learning can be dramatically increased by presenting the materials in a form that incorporates an external analogue to the elaboration. For example, noun pairs can be presented to children in the form of sentences (e.g., The fish smoked a pipe) or in the form of pictures displaying an event involving both of the objects designated by the nouns in a pair. These methods of presenting material have been shown to produce dramatic increases in the efficiency of the child's performance across the range of about four to fourteen years of age. Once again, the conclusion suggested is that younger children must receive considerable instructional help, structured support if you will, in order for them to take advantage of efficient strategies for mastering intellectual tasks.

With regard to memory, research to date suggests that the major factor that determines remembering in adults also operates in children, namely, the degree to which material has been learned in the first place. Suppose two children have learned a list of ten noun pairs to a point where they can correctly recite all the pairs at least twice in a row. Further, suppose that one of the children required thirty trials of practice in order to reach this criterion whereas the other child required only ten. If both children are tested for their recollection of the list a week later, they will probably remember approximately equal numbers of pairs correctly, despite the difference between the children in their proficiency at learning the list initially.

At present, it appears that another major feature of memory in adults is equally characteristic of children. Much of the forgetting experienced by adults is attributed to _interference_ from other material that has been learned, either prior to, or subsequent to the material in question. This same kind of effect is observed in children, suggesting that care must be taken to help the child distinguish clearly between successive sets of verbal items that he is asked to learn.

Concept Learning

Some of the research and theory related to the topic of developmental changes in concept learning in children has already been reviewed in connection with the topic of transfer. Accordingly we will restrict our attention here to issues that arise in connection with the learning of more complex concepts, especially those kinds that have been studied as a result of Piagetian theory and observation.

The most popular of the tasks used in recent research on developmental changes in the learning of complex concepts are the so-called conservation tasks. A wide variety of these tasks has been used, differing in materials, procedures and especially in the character of the judgments the child is asked to make. Most such tasks, however, share the aim of determining when children become capable of judging quantities as equivalent even though the materials differ in one or a number of other respects. An example from the conservation of number is the task of deciding whether two sets of five objects are numerically identical when the objects in one set are widely separated and the objects in the other are bunched together. Research to date seems to suggest that the capability of judging numerical equivalence does not emerge until about age six, on the average. Equivalence judgments for other kinds of quantities appear to be even more difficult as the following age estimates indicate (Reese & Lipsitt, 1970): mass, length, and area--six to seven years; weight--nine years; volume--eleven to twelve years.

There is considerable dispute both about the ages at which these skills emerge developmentally and about the mechanisms that account for their emergence. Piagetian theory emphasizes the necessity that the child attain the ability to engage in concrete operations, including those of class inclusion and reversibility, before he can accurately make equivalence judgments. Other theoretical approaches emphasize dimensional preferences and developmental changes in the child's inclination to attend to these distinctive features of materials. Still other approaches, such as Gagne's postulate the accumulation of specific prior learning as the mechanism whereby the child comes to "conserve" quantity. Finally, some theorists regard the observed age trends as attributable to changes in the tendency to use language as a tool of thinking. Whatever the interpretation, research results in this area, as in others we have reviewed, suggest that young children find concept learning and tasks that require the combination and manipulation of concepts to be extraordinarily demanding.

Since most of the implications of the theory and research we have reviewed here are very specific, it is probably not fruitful to formulate a summary statement of them. Instead, some frankly loose generalizations may be offered by way of concluding the essay. It is obvious that massive changes occur in the child's intellectual capabilities over the range from birth to nine years. Specifications of the exact ages at which the many changes emerge, however, have not yet been completed. One of the reasons for this is that children of the same ages differ from one another in a large number of ways; another reason is that the child's capability seems to vary substantially, depending on the way any given task is presented to him. Finally, two characteristics of children's intellectual performance are truly remarkable. The first is that they learn from systematic experience at very young ages indeed--from birth onward. The second is that tasks routinely regarded by adults as relatively simple, and therefore expected of children at early ages--tasks such as reading and arithmetic, require capabilities that many children seem not to achieve with ease until rather late in the age range. Thus, young children need substantial assistance if we continue to demand these rather herculean achievements of them.

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