THE COURSE OF COGNITIVE GROWTH

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I SHALL take the view in what follows that the development of human intellectual functioning from infancy to such perfection as it may reach is shaped by a series of technological advances in the use of mind. Growth depends upon the mastery of techniques and cannot be understood without reference to such mastery. These techniques are not, in the main, inventions of the individuals who are "growing up"; they are, rather, skills transmitted with varying efficiency and success by the culture—language being a prime example. Cognitive growth, then, is in a major way from the outside in as well as from the inside out.

Two matters will concern us. The first has to do with the techniques or technologies that aid growing human beings to represent in a manageable way the recurrent features of the complex environments in which they live. It is fruitful, I think, to distinguish three systems of processing information by which human beings construct models of their world: through action, through imagery, and through language. A second concern is with integration, the means whereby acts are organized into higher-order ensembles, making possible the use of larger and larger units of information for the solution of particular problems.

Let me first elucidate these two theoretical matters, and then turn to an examination of the research upon which they are based, much of it from the Center for Cognitive Studies at Harvard.

On the occasion of the One Hundredth Anniversary of the publication of Darwin's *The Origin of Species,* Washburn and Howell (1960) presented a paper at the Chicago Centennial celebration containing the following passage:

> It would now appear . . . that the large size of the brain of certain hominids was a relatively late development and that the brain evolved due to new selection pressures *after* bipedalism and consequent upon the use of tools. The tool-using, ground-living, hunting way of life created the large human brain rather than a large brained man discovering certain new ways of life. [We] believe this conclusion is the most important result of the recent fossil hominid discoveries and is one which carries far-reaching implications for the interpretation of human behavior and its origins. . . . The important point is that size of brain, insofar as it can be measured by cranial capacity, has increased some threefold subsequent to the use and manufacture of implements. . . . The uniqueness of modern man is seen as the result of a technical-social life which tripled the size of the brain, reduced the face, and modified many other structures of the body [p. 49 f.].

This implies that the principal change in man over a long period of years—perhaps 500,000 thousand—has been alloplastic rather than autoplastic. That is to say, he has changed by linking himself with new, external implementation systems rather than by any conspicuous change in morphology —"evolution-by-prosthesis," as Weston La Barre (1954) puts it. The implement systems seem to have been of three general kinds—*amplifiers of human motor capacities* ranging from the cutting tool through the lever and wheel to the wide variety of modern devices; *amplifiers of sensory capacities* that include primitive devices such as smoke signaling and modern ones such as magnification and radar sensing, but also likely to include such "software" as those conventionalized perceptual shortcuts that can be applied to the redundant sensory environment; and finally *amplifiers of human ratiocinative capacities* of infinite variety ranging from language systems to myth and theory and explanation. All of these forms of amplification are in major or minor degree conventionalized and transmitted by the culture, the last of them probably the most since ratiocinative amplifiers involve symbol systems governed by rules that must, for effective use, be shared.

Any implement system, to be effective, must produce an appropriate internal counterpart, an appropriate skill necessary for organizing sensorimotor acts, for organizing percepts, and for organizing our thoughts in a way that matches them to the requirements of implement systems. These internal skills, represented genetically as capacities, are slowly selected in evolution. In the deepest

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sense, then, man can be described as a species that has become specialized by the use of technological implements. His selection and survival have depended upon a morphology and set of capacities that could be linked with the alloplastic devices that have made his later evolution possible. We move, perceive, and think in a fashion that depends upon techniques rather than upon wired-in arrangements in our nervous system.

Where representation of the environment is concerned, it too depends upon techniques that are learned—and these are precisely the techniques that serve to amplify our motor acts, our perceptions, and our ratiocinative activities. We know and respond to recurrent regularities in our environment by skilled and patterned acts, by conventionalized spatioqualitative imagery and selective perceptual organization, and through linguistic encoding which, as so many writers have remarked, places a selective lattice between us and the physical environment. In short, the capacities that have been shaped by our evolution as tool users are the ones that we rely upon in the primary task of representation—the nature of which we shall consider in more detail directly.

As for integration, it is a truism that there are very few single or simple adult acts that cannot be performed by a young child. In short, any more highly skilled activity can be decomposed into simpler components, each of which can be carried out by a less skilled operator. What higher skills require is that the component operations be combined. Maturation consists of an orchestration of these components into an integrated sequence. The "distractability," so-called, of much early behavior may reflect each act's lack of imbeddedness in what Miller, Galanter, and Pribram (1960), speak of as "plans." These integrated plans, in turn, reflect the routines and subroutines that one learns in the course of mastering the patterned nature of a social environment. So that integration, too, depends upon patterns that come from the outside in—an internalization of what Roger Barker (1963) has called environmental "behavior settings."

If we are to benefit from contact with recurrent regularities in the environment, we must represent them in some manner. To dismiss this problem as "mere memory" is to misunderstand it. For the most important thing about memory is not storage of past experience, but rather the retrieval of what is relevant in some usable form. This depends upon how past experience is coded and processed so that it may indeed be relevant and usable in the present when needed. The end product of such a system of coding and processing is what we may speak of as a representation.

I shall call the three modes of representation mentioned earlier enactive representation, iconic representation, and symbolic representation. Their appearance in the life of the child is in that order, each depending upon the previous one for its development, yet all of them remaining more or less intact throughout life—barring such early accidents as blindness or deafness or cortical injury. By enactive representation I mean a mode of representing past events through appropriate motor response. We cannot, for example, give an adequate description of familiar sidewalks or floors over which we habitually walk, nor do we have much of an image of what they are like. Yet we get about them without tripping or even looking much. Such segments of our environment—bicycle riding, tying knots, aspects of driving—get represented in our muscles, so to speak. Iconic representation summarizes events by the selective organization of percepts and of images, by the spatial, temporal, and qualitative structures of the perceptual field and their transformed images. Images "stand for" perceptual events in the close but conventionally selective way that a picture stands for the object pictured. Finally, a symbol system represents things by design features that include remoteness and arbitrariness. A word neither points directly to its referent here and now, nor does it resemble it as a picture. The lexeme "Philadelphia" looks no more like the city so designated than does a nonsense syllable. The other property of language that is crucial is its productiveness in combination, far beyond what can be done with images or acts. "Philadelphia is a lavendar sachet in Grandmother's linen closet," or $(x + 2)^2 = x^2 + 4x + 4 = x(x + 4) + 4$.

An example or two of enactive representation underlines its importance in infancy and in disturbed functioning, while illustrating its limitations. Piaget (1954) provides us with an observation from the closing weeks of the first year of life. The child is playing with a rattle in his crib. The rattle drops over the side. The child moves his clenched hand before his face, opens it, looks for the rattle. Not finding it there, he moves his hand, closed again, back to the edge of the crib, shakes it with movements like those he uses in shaking the rattle. Thereupon he moves his closed hand back toward his face, opens it, and looks. Again no rattle; and so he tries again. In several months, the child has benefited from experience to the degree that the rattle and action become separated. Whereas earlier he would not show signs of missing the rattle when it was removed unless he had begun reaching for it, now he cries and searches when the rattle is presented for a moment and hidden by a cover. He no longer repeats a movement to restore the rattle. In place of representation by action alone—where "existence" is defined by the compass of present action—it is now defined by an image that persists autonomously.

A second example is provided by the results of injury to the occipital and temporal cortex in man (Hanfmann, Rickers-Ovsiankina, & Goldstein, 1944). A patient is presented with a hard-boiled egg intact in its shell, and asked what it is. Holding it in his hand, he is embarrassed, for he cannot name it. He makes a motion as if to throw it and halts himself. Then he brings it to his mouth as if to bite it and stops before he gets there. He brings it to his ear and shakes it gently. He is puzzled. The experimenter takes the egg from him and cracks it on the table, handing it back. The patient then begins to peel the egg and announces what it is. He cannot identify objects without reference to the action he directs toward them.

The disadvantages of such a system are illustrated by Emerson's (1931) experiment in which children are told to place a ring on a board with seven rows and six columns of pegs, copying the position of a ring put on an identical board by the experimenter. Children ranging from 3 to 12 were examined in this experiment and in an extension of it carried out by Werner (1948). The child's board could be placed in various positions relative to the experimenter's: right next to it, 90 degrees rotated away from it, 180 degrees rotated, placed face to face with it so that the child has to turn full around to make his placement, etc. The older the child, the better his performance. But the younger children could do about as well as the oldest so long as they did not have to change their own position vis-à-vis the experimenter's board in order to make a match on their own board. The more they had to turn, the more difficult the task. They were clearly depending upon their bodily orientation toward the experimenter's board to guide them. When this orientation is disturbed by having to turn, they lose the position on the board. Older children succeed even when they must turn, either by the use of imagery that is invariant across bodily displacements, or, later, by specifying column and row of the experimenter's ring and carrying the symbolized self-instruction back to their own board. It is a limited world, the world of enactive representation.

We know little about the conditions necessary for the growth of imagery and iconic representation, or to what extent parental or environmental intervention affects it during the earliest years. In ordinary adult learning a certain amount of motoric skill and practice seems to be a necessary precondition for the development of a simultaneous image to represent the sequence of acts involved. If an adult subject is made to choose a path through a complex bank of toggle switches, he does not form an image of the path, according to Mandler (1962), until he has mastered and overpracticed the task by successive manipulation. Then, finally, he reports that an image of the path has developed and that he is now using it rather than groping his way through.

Our main concern in what follows is not with the growth of iconic representation, but with the transition from it to symbolic representation. For it is in the development of symbolic representation that one finds, perhaps, the greatest thicket of psychological problems. The puzzle begins when the child first achieves the use of productive grammar, usually late in the second year of life. Toward the end of the second year, the child is master of the single-word, agrammatical utterance, the so-called holophrase. In the months following, there occurs a profound change in the use of language. Two classes of words appear—a pivot class and an open class—and the child launches forth on his career in combinatorial talking and, perhaps, thinking. Whereas before, lexemes like *allgone* and *mummy* and *sticky* and *bye-bye* were used singly, now, for example, *allgone* becomes a pivot word and is used in combination. Mother washes jam off the child's hands; he says *allgone sticky*. In the next days, if his speech is carefully followed (Braine, 1963), it will be apparent that he is trying out the limits of the pivot combinations, and one will even find constructions that have an extraordinary capacity for representing complex sequences—like *allgone bye-bye* after a visitor has departed. A recent and in-

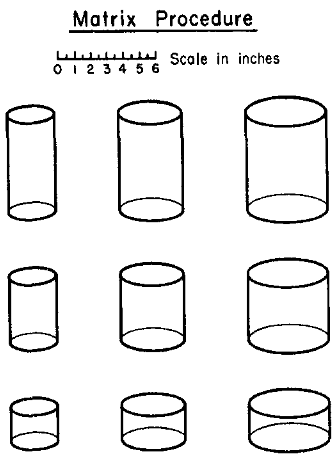


FIG. 1. Array of glasses used in study of matrix ordering (Bruner & Kenney, in press).

genious observation by Weir (1962) on her 2½-year-old son, recording his speech musings after he was in bed with lights out, indicates that at this stage there is a great deal of metalinguistic combinatorial play with words in which the child is exploring the limits of grammatical productiveness.

In effect, language provides a means, not only for representing experience, but also for transforming it. As Chomsky (1957) and Miller (1962) have both made clear in the last few years, the transformational rules of grammar provide a syntactic means of reworking the "realities" one has encountered. Not only, if you will, did the dog bite the man, but the man was bitten by the dog and perhaps the man was not bitten by the dog or was the man not bitten by the dog. The range of reworking that is made possible even by the three transformations of the passive, the negative, and the query is very striking indeed. Or the ordering device whereby the comparative mode makes it possible to connect what is *heavy* and what is *light* into the ordinal array of *heavy* and *less heavy* is again striking. Or, to take a final example, there is the discrimination that is made possible by the growth of attribute language such that the global dimension *big* and *little* can now be decomposed into *tall* and *short* on the one hand and *fat* and *skinny* on the other.

Once the child has succeeded in internalizing language as a cognitive instrument, it becomes possible for him to represent and systematically transform the regularities of experience with far greater flexibility and power than before. Interestingly enough, it is the recent Russian literature, particularly Vygotsky's (1962) book on language and thought, and the work of his disciple, Luria (1961), and his students (Abramyan, 1958; Martsinovskaya, undated) that has highlighted these phenomena by calling attention to the so-called second-signal system which replaces classical conditioning with an internalized linguistic system for shaping and transforming experience itself.

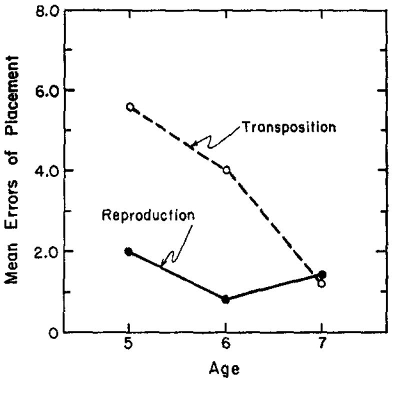
If all these matters were not of such complexity and human import, I would apologize for taking so much time in speculation. We turn now to some new experiments designed to shed some light on the nature of representation and particularly upon the transition from its iconic to its symbolic form.

Let me begin with an experiment by Bruner and Kenney (in press) on the manner in which children between 5 and 7 handle a double classification matrix. The materials of the experiment are nine plastic glasses, arranged so that they vary in 3 degrees of diameter and 3 degrees of height. They are set before the child initially, as in Figure 1, on a 3 × 3 grid marked on a large piece of cardboard. To acquaint the child with the matrix, we first remove one, then two, and then three glasses from the matrix, asking the child to replace them. We also ask the children to describe how the glasses in the columns and rows are alike and how they differ. Then the glasses are scrambled and we ask the child to make something like what was there before by placing the glasses on the same grid that was used when the task was introduced. Now we scramble the glasses once more, but this time we place the glass that was formerly in the southwest corner of the grid in the southeast corner (it is the shortest, thinnest glass) and ask the child if he can make something like what was there before, leaving the one glass where we have just put it. That is the experiment.

The results can be quickly told. To begin with, there is no difference between ages 5, 6, and 7 either in terms of ability to replace glasses taken from the matrix or in building a matrix once it has been scrambled (but without the transposed glass). Virtually all the children succeed. Interestingly enough, *all* the children rebuild the matrix to match the original, almost as if they were copying what was there before. The only difference is that the older children are quicker.

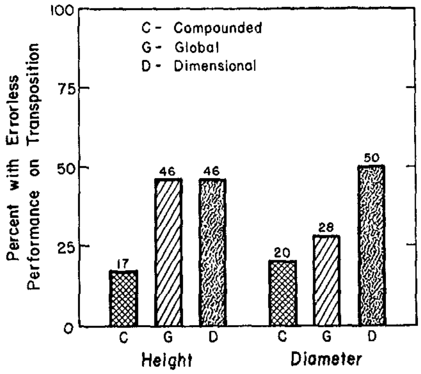
Now compare the performance of the three ages in constructing the matrix with a single member transposed. Most of the 7-year-olds succeed in the transposed task, but hardly any of the youngest children. Figure 2 presents the results graphically. The youngest children seem to be dominated by an image of the original matrix. They try to put the transposed glass "back where it belongs," to rotate the cardboard so that "it will be like before," and sometimes they will start placing a few glasses neighboring the transposed glass correctly only to revert to the original arrangement. In several instances, 5- or 6-year-olds will simply try to reconstitute the old matrix, building right over the transposed glass. The 7-year-old, on the other hand, is more likely to pause, to treat the transposition as a problem, to talk to himself about "where this should go." The relation of place and size is for him a problem that requires reckoning, not simply copying.

Now consider the language children use for describing the dimensions of the matrix. Recall that the children were asked how glasses in a row and in a column were alike and how they differed. Children answered in three distinctive linguistic modes. One was *dimensional,* singling out two ends of an attribute—for example, "That one is higher, and that one is shorter." A second was *global* in nature. Of glasses differing only in height the child says, "That one is bigger and that one is little." The same words could be used equally well for diameter or for nearly any other magnitude. Finally, there was *confounded* usage: "That one is tall and that one is little," where a dimensional term is used for one end of the continuum and a global term for the other. The children who used



Reconstruction of Matrix

FIG. 2. Mean number of errors made by children in reproducing and transposing a 3 × 3 matrix (Bruner & Kenney, in press).



Descriptive Language Use

FIG. 3. Percentage of children (aged 5–7) using different language patterns who reproduced transposed matrix errorlessly (Bruner & Kenney, in press).

confounded descriptions had the most difficulty with the transposed matrix. Lumping all ages together, the children who used confounded descriptions were twice as likely to fail on the transposition task as those who used either dimensional or global terms. *But the language the children used had no relation whatsoever to their performance in reproducing the first untransposed matrix.* Inhelder and Sinclair [2] in a recent communication also report that confounded language of this kind is associated with failure on conservation tasks in children of the same age, a subject to which we shall turn shortly.

The findings of this experiment suggest two things. First, that children who use iconic representation are more highly sensitized to the spatial-qualitative organization of experience and less to the ordering principles governing such organization. They can recognize and reproduce, but cannot produce new structures based on rule. And second, there is a suspicion that the language they bring to bear on the task is insufficient as a tool for ordering. If these notions are correct, then certain things should follow. For one thing, *improvement* in language should aid this type of problem solving. This remains to be investigated. But it is also reasonable to suppose that *activation* of language habits that the child has already mastered might improve performance as well—a hypothesis already suggested by the findings of Luria's students (e.g., Abramyan, 1958). Now, activation can be achieved by two means: One is by having the

[2] Bärbel Inhelder and Mimi Sinclair, personal communication, 1963.

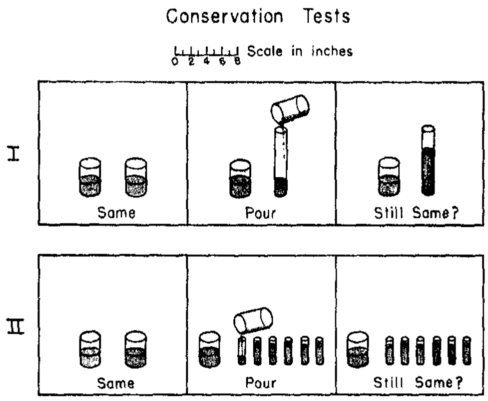


FIG. 4. Two Geneva tests for conservation of liquid volume across transformations in its appearance (Piaget & Inhelder, 1962).

child "say" the description of something before him that he must deal with symbolically. The other is to take advantage of the remoteness of reference that is a feature of language, and have the child "say" his description in the absence of the things to be described. In this way, there would be less likelihood of a perceptual-iconic representation becoming dominant and inhibiting the operation of symbolic processes. An experiment by Françoise Frank (in press) illustrates this latter approach—the effects of saying before seeing.

Piaget and Inhelder (1962) have shown that if children between ages 4 and 7 are presented two identical beakers which they judge equally full of water, they will no longer consider the water equal if the contents of one of the beakers is now poured into a beaker that is either wider or thinner than the original. If the second beaker is thinner, they will say it has more to drink because the water is higher; if the second beaker is wider, they will say it has less because the water is lower. Comparable results can be obtained by pouring the contents of one glass into several smaller beakers. In Geneva terms, the child is not yet able to conserve liquid volume across transformations in its appearance. Consider how this behavior can be altered.

Françoise Frank first did the classic conservation tests to determine which children exhibited conservation and which did not. Her subjects were 4, 5, 6, and 7 years old. She then went on to other procedures, among which was the following. Two standard beakers are partly filled so that the child judges them to contain equal amounts of water. A wider beaker of the same height is introduced and the three beakers are now, except for their tops, hidden by a screen. The experimenter pours from a standard beaker into the wider beaker. The child, without seeing the water, is asked which has more to drink, or do they have the same amount, the standard or the wider beaker. The results are in Figure 6. In comparison with the unscreened pretest, there is a striking increase in correct equality judgments. Correct responses jump from 0% to 50% among the 4s, from 20% to 90% among the 5s, and from 50% to 100% among the 6s. With the screen present, most children justify their cor-

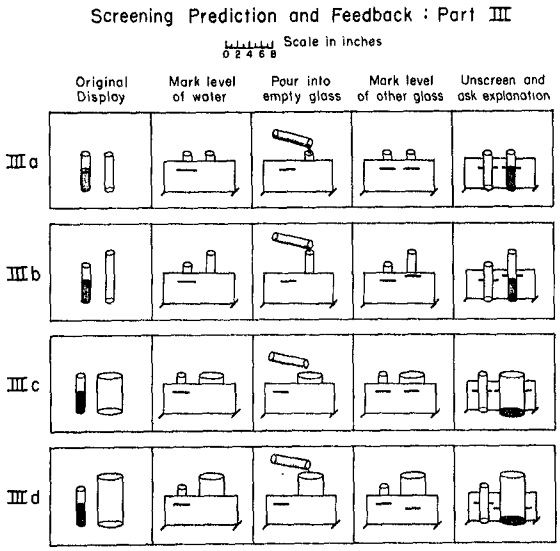


FIG. 5. One procedure used in study of effect of language activation on conservation (Frank, in press).

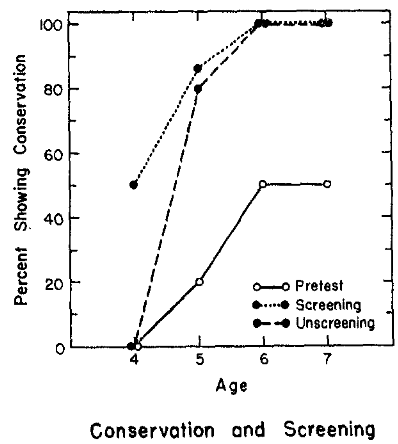


FIG. 6. Percentage of children showing conservation of liquid volume before and during screening and upon unscreening of the displays (Frank, in press).

rect judgment by noting that "It's the same water," or "You only poured it."

Now the screen is removed. All the 4-year-olds change their minds. The perceptual display overwhelms them and they decide that the wider beaker has less water. But virtually all of the 5-year-olds stick to their judgment, often invoking the difference between appearance and reality—"It looks like more to drink, but it is only the same because it is the same water and it was only poured from there to there," to quote one typical 5-year-old. And all of the 6s and all the 7s stick to their judgment. Now, some minutes later, Frank does a posttest on the children using a tall thin beaker along with the standard ones, and no screen, of course. The 4s are unaffected by their prior experience: None of them is able to grasp the idea of invariant quantity in the new task. With the 5s, instead of 20% showing conservation, as in the pretest, 70% do. With both 6s and 7s, conservation increases from 50% to 90%. I should mention that control groups doing just a pretest and posttest show no significant improvement in performance.

A related experiment of Nair's (1963) explores the arguments children use when they solve a conservation task correctly and when they do not. Her subjects were all 5-year-olds. She transferred water from one rectangular clear plastic tank to another that was both longer and wider than the first. Ordinarily, a 5-year-old will say there is less water in the second tank. The water is, of course, lower in the second tank. She had a toy duck swimming in the first container, and when the water was poured into the new container, she told the child that "The duck was taking his water with him."

Three kinds of arguments were set forth by the children to support their judgments. One is perceptual—having to do with the height, width, or apparent "bigness" of the water. A second type has to do with action: The duck took the water along, or the water was only poured. A third one, "transformational" argument, invokes the reversibility principle: If you poured the water back into the first container, it would look the same again.[3] Of the children who thought the water was not

[3] Not one of the 40 children who participated in this experiment used the compensation argument—that though the water was lower it was correspondingly wider and was, therefore, the same amount of water. This type of reasoning by compensation is said by Piaget and Inhelder (1962) to be the basis of conservation.

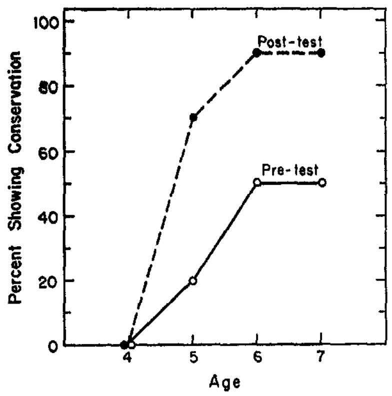


FIG. 7. Percentage of children showing conservation of liquid volume in identical pretest and posttest run after completion of experiment (Frank, in press).

equal in amount after pouring, 15% used nonperceptual arguments to justify their judgment. Of those who recognized the equality of the water, two-thirds used nonperceptual arguments. It is plain that if a child is to succeed in the conservation task, he must have some internalized verbal formula that shields him from the overpowering appearance of the visual displays much as in the Frank experiment. The explanations of the children who lacked conservation suggest how strongly oriented they were to the visual appearance of the displays they had to deal with.

Consider now another experiment by Bruner and Kenney (in press) also designed to explore the border between iconic and symbolic representation. Children aged 5, 6, and 7 were asked to say which of two glasses in a pair was fuller and which emptier. "Fullness" is an interesting concept to work with, for it involves in its very definition a ratio or proportion between the volume of a container and the volume of a substance contained. It is difficult for the iconically oriented child to see a half-full barrel and a half-filled thimble as equally full, since the former looms larger in every one of the attributes that might be perceptually associated with volume. It is like the old riddle of which is heavier, a pound of lead or a pound of feathers. To make a correct judgment of fullness or emptiness, the child must use a symbolic operation, somewhat like computing a ratio, and resist the temptation to use perceptual appearance—that is, unless he finds some happy heuristic to save him the labor of such a computation. Figure 8 contains the

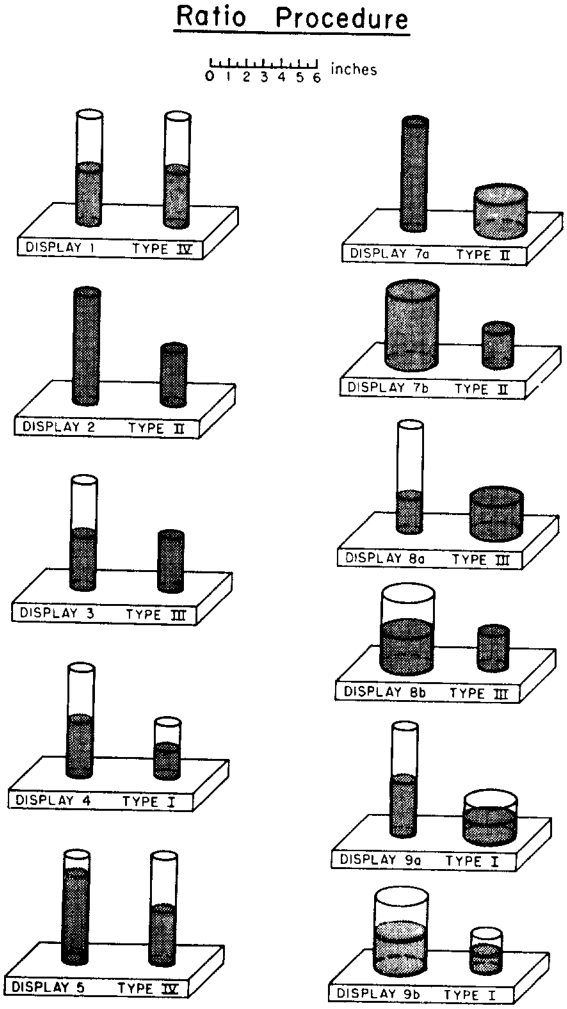


FIG. 8. Eleven pairs of glasses to be judged in terms of which glass is fuller and which emptier (Bruner & Kenney, in press).

11 pairs of glasses used, and they were selected with a certain malice aforethought.

There are four types of pairs. In Type I (Displays 4, 9a, and 9b), the glasses are of unequal volume, but equally, though fractionally, full. In Type II (Displays 2, 7a, and 7b) again the glasses are of unequal volume, but they are completely full. Type III (Displays 3, 8a, and 8b) consists of two glasses of unequal volume, one filled and the other part filled. Type IV consists of identical glasses, in one case equally filled, in another unequally (Displays 1 and 5).

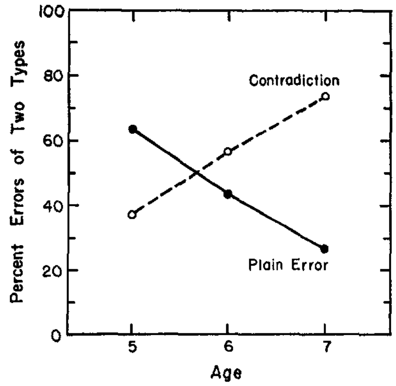
All the children in the age range we have studied use pretty much the same criteria for judging *fullness,* and these criteria are based on directly observable sensory indices rather than upon proportion. That glass is judged fuller that has the greater apparent volume of water, and the favored indication of greater volume is water level; or where that is equated, then width of glass will do; and when width and water level are the same, then height of glass will prevail. But now consider the judgments made by the three age groups with respect to which glass in each pair is *emptier.* The older children have developed an interesting consistency based on an appreciation of the complementary relation of filled and empty space—albeit an incorrect one. For them "emptier" means the glass that has the largest apparent volume of unfilled space, just as "fuller" meant the glass that had the largest volume of filled space. In consequence, their responses seem logically contradictory. For the glass that is judged fuller also turns out to be the glass that is judged emptier—given a large glass and a small glass, both half full. The younger children, on the other hand, equate emptiness with "littleness": That glass is emptier that gives the impression of being smaller in volume of liquid. If we take the three pairs of glasses of Type I (unequal volumes, half filled) we can see how the judgments typically distribute themselves. Consider only the errors. The glass with the larger volume of empty space is called emptier by 27% of the erring 5-year-olds, by 53% of the erring 6-year-olds, and by 72% of erring 7-year-olds. But the glass with the smallest volume of water is called emptier by 73% of the 5-year-olds who err, 47% of the 6s, and only 28% of the 7s. When the children are asked for their reasons for judging one glass as emptier, there is further confirmation: Most of the younger children justify it by pointing

TABLE 1

PERCENTAGE OF ERRONEOUS JUDGMENTS OF WHICH OF TWO GLASSES IS EMPTIER BASED ON TWO CRITERIA FOR DEFINING THE CONCEPT

Criterion for "emptier" judgment	Age		
	5	6	7
Greater empty space	27%	53%	72%
Smaller volume of liquid	73%	47%	28%
	100%	100%	100%
Percentage correct	9%	8%	17%
N =	30	30	30

Note.—Criteria are greater volume of empty space and lesser volume of water. From Bruner and Kenney (in press).



Proportion of
Two Types of Error

FIG. 9. Percentage of children at three ages who make contradictory and plain errors in judging which of two glasses is fuller and which emptier. (A contradictory error is calling the same glass both fuller or emptier or calling them equally full but not equally empty or vice versa. A plain error is calling one glass fuller and the other emptier, but incorrectly. From Bruner & Kenney, in press.)

to "littleness" or "less water" or some other aspect of diminutiveness. And most of the older children justify their judgments of emptiness by reference to the amount of empty space in the vessel.

The result of all this is, of course, that the "logical structure" of the older children seems to go increasingly awry. But surely, though Figure 9 shows that contradictory errors steadily increase with age (calling the same glass fuller and emptier or equally full but not equally empty or vice versa), the contradiction is a by-product of the method of dealing with attributes. How shall we interpret these findings? Let me suggest that what is involved is a translation difficulty in going from the perceptual or iconic realm to the symbolic. If you ask children of this age whether something can be fuller and also emptier, they will smile and think that you are playing riddles. They are aware of the contrastive nature of the two terms. Indeed, even the very young child has a good working language for the two poles of the contrast: "all gone" for completely empty and "spill" or "tippy top" for completely full. Recall too that from 5 to 7, there is perfect performance in judging which of two identical beakers is fuller and emptier. The difference between the younger and the older child is in the number of attributes that are being attended to in situations involving fullness and emptiness: The younger child is attending to one—the volume of water; the older to two—the volume of filled space and the volume of empty space. The young child is applying a single contrast pair—full-empty —to a single feature of the situation. The older child can attend to two features, but he does not yet have the means for relating them to a third, the volume of the container per se. To do so involves being able to deal with a relation in the perceptual field that does not have a "point-at-able" or ostensive definition. Once the third term is introduced—the volume of the glass—then the symbolic concept of proportion can come to "stand for" something that is not present perceptually. The older child is on the way to achieving the insight, in spite of his contradictions. And, interestingly enough, if we count the number of children who justify their judgments of fuller and emptier by pointing to *several* rather than a single attribute, we find that the proportion triples in both cases between age 5 and age 7. The older child, it would seem, is ordering his perceptual world in such a way that, shortly, he will be able to apply concepts of relationship that are not dependent upon simple ostensive definition. As he moves toward this more powerful "technology of reckoning," he is led into errors that seem to be contradictory. What is particularly telltale is the fact, for example, that in the Type III displays, younger children sometimes seem to find the judgment easier than older children—pointing to the fuller by placing their finger on the rim of the full member and pointing to the emptier with the remark that "It is not to the top." The older child (and virtually never the younger one) gets all involved in the judgment of "fuller by apparent filled volume" and then equally involved in the judgment of "emptier by apparent empty volume" and such are his efforts that he fails to note his contradiction when dealing with a pair like Display 8b.

Turn now to a quite different experimental pro-

TABLE 2

PERCENTAGE OF CHILDREN WHO JUSTIFY JUDGMENTS OF "FULLER" AND "EMPTIER" BY MENTIONING MORE THAN A SINGLE ATTRIBUTE

Age	"Fuller" judgments	"Emptier" judgments	N
5	7.2%	4.1%	30
6	15.6%	9.3%	30
7	22.2%	15.6%	30

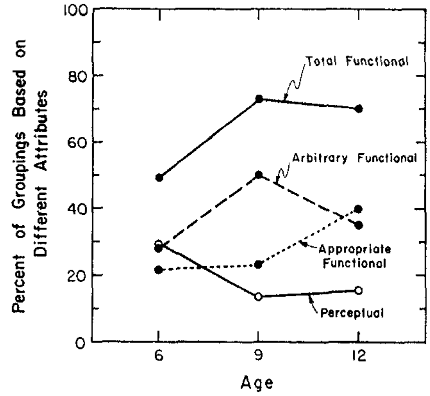


FIG. 10. Features of objects used by children of different ages as a basis for placing the objects in equivalence groups (Olver, 1961).

cedure that deals with the related concept of equivalence—how seemingly different objects are grouped into equivalence classes. In the two experiments to be cited, one by Olver (1961), the other by Rigney (1962), children are given words or pictures to sort into groups or to characterize in terms of how they are alike. The two sets of results, one for words, the other for pictures, obtained for children between 6 and 14, can be summarized together. One may distinguish two aspects of grouping—the first has to do with the features or attributes that children use as a criterion for grouping objects: *perceptual features* (the color, size, pattern, etc.), *arbitrary functional features* (what I can do with the objects regardless of their usual use: You can make noise with a newspaper by crumpling it and with a book by slamming it shut, etc.), *appropriate functional features* (potato, peach, banana, and milk are characterized "You can eat them"). But grouping behavior can also be characterized in terms of the syntactical structure of the equivalence sets that the child develops. There are, first, what Vygotsky (1962) has called *heaps:* collections put together in an arbitrary way simply because the child has decided to put them together that way. Then there are *complexes:* The various members of a complex are included in the class in accordance with a rule that does not account uniformly for the inclusion of all the members. Edge matching is one such rule: Each object is grouped into a class on the basis of its similarity with a neighboring object. Yet no two neighboring pieces may be joined by the same similarity. Another type of complexive grouping is thematic: Here objects are put together by virtue of participating in a sentence or a little story. More sophisticated is a key ring in which one organizing object is related to all others but none of those to each other. And finally, considerably more sophisticated than heaps and complexes, there are *superordinate concepts,* in which one universal rule of inclusion accounts for all the objects in the set—all men and women over 21 are included in the class of voters provided they meet certain residence requirements.

The pattern of growth is revealing of many of the trends we have already discussed, and provides in addition a new clue. Consider first the attributes or features of objects that children at different ages use as a basis for forming equivalence groups. As Figure 10 indicates, the youngest children rely more heavily on perceptual attributes than do the others. As they grow older, grouping comes to depend increasingly upon the functional properties of things —but the transitional phase is worth some attention, for it raises anew the issue of the significance of egocentrism. For the first functional groupings to appear are of an arbitrary type—what "I" or "you" can do to objects that renders them alike, rather than what is the conventional use or function to which objects can be put. During this stage of "egocentric functionalism," there is a corresponding rise in the use of first- and second-person personal pronouns: "I can do thus and so to this object; I can do the same to this one," etc. Gradually, with increasing maturity the child shifts to an appropriate and less egocentric form of using

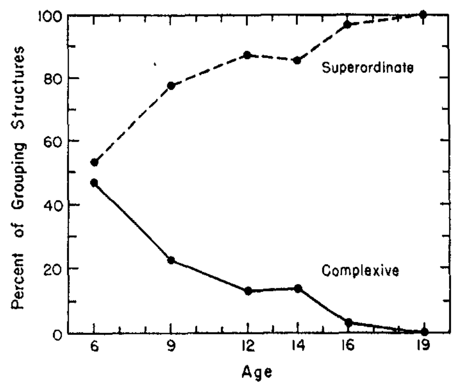


FIG. 11. The use of two rules of equivalence grouping found in children of different ages (Olver, 1961).

functional groupings. The shift from perceptual to functional groupings is accompanied by a corresponding shift in the syntactical structure of the groups formed. Complexive groupings steadily dwindle; superordinate groupings rise, until the latter almost replace the former in late adolescence. It is difficult to tell which is the pacemaker in this growth—syntax or the semantic basis of grouping.

Rigney reports one other matter of some interest. Her young subjects formed groups of any size they wished, choosing pictures from a display board of several dozen little water colors. She observed that the most perceptually based groups and the ones most often based on complexive grouping principles were pairs. A count of these revealed that 61% of all the groups made by 6-year-olds were such pairs, 36% of those made by 8-year-olds, and only 25% of the groupings of 11-year-olds.

On the surface, this set of findings—Olver's and Rigney's alike—seems to point more to the decline of a preference for perceptual and iconic ways of dealing with objects and events, particularly with their grouping. But closer inspection suggests still another factor that is operating. In both cases, there is evidence of the development of hierarchical structure and rules for including objects in superordinate hierarchies. Hierarchical classification is surely one of the most evident properties of the structure of language—hierarchical grouping that goes beyond mere perceptual inclusion. Complexive structures of the kind described earlier are much more dominated by the sorts of associative principles by which the appearance of objects leads to their spontaneous grouping in terms of similarity or contiguity. As language becomes more internalized, more guiding as a set of rules for organizing events, there is a shift from the associative principles that operate in classical perceptual organization to the increasingly abstract rules for grouping events by the principles of inclusion, exclusion, and overlap, the most basic characteristics of any hierarchical system.

We have said that cognitive growth consists in part in the development of systems of representation as means for dealing with information. The growing child begins with a strong reliance upon learned action patterns to represent the world around him. In time, there is added to this technology a means for simultanizing regularities in experience into images that stand for events in the way that pictures do. And to this is finally added a technology of translating experience into a symbol system that can be operated upon by rules of transformation that greatly increase the possible range of problem solving. One of the effects of this development, or possibly one of its causes, is the power for organizing acts of information processing into more integrated and long-range problem solving efforts. To this matter we turn next.

Consider in rapid succession three related experiments. All of them point, I think, to the same conclusion.

The first is by Huttenlocher (in press), a strikingly simple study, performed with children between the ages of 6 and 12. Two light switches are before the child; each can be in one of two positions. A light bulb is also visible. The child is asked to tell, on the basis of turning only one switch, what turns the light on. There are four ways in which the presentations are made. In the first, the light is off initially and when the child turns a switch, the light comes on. In the second, the light is on and when the child turns a switch, it goes off. In the third, the light is on and when the child turns a switch, it stays on. In the fourth and final condition, the light is off and when the child turns a switch, it stays off. Now what is intriguing about this arrangement is that there are different numbers of inductive steps required to make a correct inference in each task. The simplest condition is the off-on case. The position to which the switch has just been moved is responsible for the light going on. Intermediate difficulty should be experienced with the on-off condition. In the on-off case, two connected inferences are required: The present position achieved is rejected and the original position of the switch that has been turned is responsible for lighting the bulb. An even larger number of consecutive acts is required for success in the on-on case: The present position of the turned switch is rejected, the original position as well and the present position of the *other* switch is responsible. The off-off case requires four steps: rejecting the present position of the turned switch, its original position, and the present position of the other switch, finally accepting the alternative position of the unturned switch. The natures of the individual steps are all the same. Success in the more complex cases depends upon being able to integrate them consecutively.

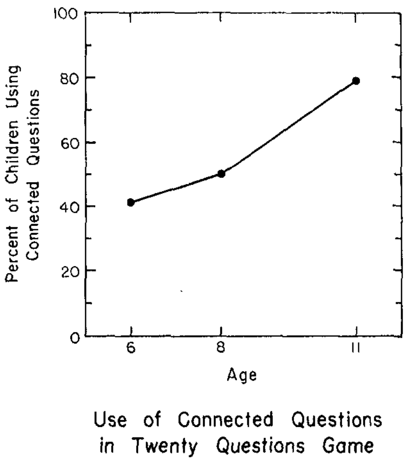


FIG. 12. The proportion of children at different ages who use connected questions in a Twenty Questions game (Mosher, 1962).

Huttenlocher's results show that the 6-year-olds are just as capable as their elders of performing the elementary operation involved in the one-step case: the on-off display. They, like the 9s and 12s, make nearly perfect scores. But in general, the more inferential steps the 6-year-old must make, the poorer his performance. By age 12, on the other hand, there is an insignificant difference between the tasks requiring one, two, three, or four connected inferences.

An experiment by Mosher (1962) underlines the same point. He was concerned with the strategies used by children from 6 to 11 for getting information in the game of Twenty Questions. They were to find out by "yes-no" questions what caused a car to go off the road and hit a tree. One may distinguish between connected constraint-locating questions ("Was it night-time?" followed up appropriately) and direct hypothesis-testing questions ("Did a bee fly in the window and sting the man on the eye and make him go off the road and hit the tree?"). From 6 to 11, more and more children use constraint-locating, connected questioning. Let me quote from Mosher's account.

We have asked children . . . after they have played their games, to tell us which of two questions they would rather have the answer to, if they were playing the games again—one of them a typical constraint-seeking question ("Was there anything wrong with the man?") and the other a typical discrete test of an hypothesis ("Did the man have a heart attack?"). All the eleven-year-olds and all the eight-year-olds choose the constraint-seeking question, but only 29% of the six-year-olds do [p. 6].

The questions of the younger children are all one-step substitutes for direct sense experience. They are looking for knowledge by single questions that provide the answer in a finished form. When they succeed they do so by a lucky question that hits an immediate, perceptible cause. When the older child receives a "yes" answer to one of his constraint-locating questions, he most often follows up by asking another. When, on the rare occasions that a younger child asks a constraint question and it is answered "yes," he almost invariably follows it up with a specific question to test a concrete hypothesis. The older child can accrete his information in a structure governed by consecutive inference. The younger child cannot.

Potter's (in press) study of the development of perceptual recognition bears on the same point. Ordinary colored photographs of familiar scenes are presented to children between 6 and 12, the pictures coming gradually into focus. Let me sum up one part of the results very briefly. Six-year-olds produce an abundance of hypotheses. But they rarely try to match new hypotheses to previous ones. "There is a big tower in the middle and a road over there and a big ice cream cone through the middle of the tower and a pumpkin on top." It is like a random collage. The 9-year-old's torrent of hypotheses, on the other hand, shows a sense of consistency about what is likely to appear with what. Things are in a context of likelihood, a frame of reference that demands internal consistency. Something is seen as a merry-go-round, and the child then restricts later hypotheses to the other things to be found in an amusement park. The adolescent operates under even more highly organized sequential constraints: He occasionally develops his initial hypotheses from what is implied by the properties of the picture, almost by intersection—"It is red and shiny and metallic: It must be a coffee-pot." Once such constraints are established, the order of hypotheses reflects even more the need to build up a consistent world of objects—even to the point of failing to recognize things that do not fit it.

What shall we make of these three sets of findings—that older children are able to cumulate information by asking questions in a directed sequence leading to a final goal, and that they are capable of recognizing visual displays in a manner governed by a dominating frame of reference that transcends momentary and isolated bits of information? Several points seem apparent. The first is that as children mature, they are able to use indirect information based on forms of information processing other than the act of pointing to what is immediately present. They seem, in short, to make remote reference to states and constraints that are not given by the immediate situation, to go beyond the information given. Second, and this is a matter that has already been discussed, they seem to be able to cumulate information into a structure that can be operated upon by rules that transcend simple association by similarity and contiguity. In the case of Twenty Questions, the rule is best described as implication—that knowing one thing implies certain other things and eliminates still others. In the experiments with the light switches, it is that if the present state does not produce the effect, then there is a system for tracing back to the other states that cause the light to go on. Where perceptual recognition is concerned, the rule is that a piece of information from one part of the display implies what other parts might be. The child, in sum, is translating redundancy into a manipulable model of the environment that is governed by rules of implication. It is this model of the environment that permits him to go beyond the information before him. I would suggest that it is this new array of cognitive equipment that permits the child to transcend momentaneity, to integrate longer sequences of events.

Let me urge, moreover, that such a system of processing environmental events depends upon the translation of experience into symbolic form. Such a translation is necessary in order for there to be the kind of remoteness of reference as is required when one deals with indirect information. To transcend the immediately perceptual, to get beyond what is vividly present to a more extended model of the environment, the child needs a system that permits him to deal with the nonpresent, with things that are remote in space, qualitative similarity, and time, from the present situation. Hockett (1959), in describing the design features of language includes this feature as crucial. He is referring to human speech as a system of communication. The same point can be made about language as an instrument of thought. That humans have the *capacity* for using speech in this way is only part of the point. What is critical is that the capacity is *not* used until it is coupled with the technology of language in the cognitive operations of the child.

The same can be said for the models of the environment that the child constructs to go beyond present information. This is not to say that nonverbal animals cannot make inferences that go beyond the present stimulus: Anticipatory activity is the rule in vertebrates. But the models that the growing child constructs seem not to be anticipatory, or inferential, or probabilistic-frequency models. They seem to be governed by rules that can more properly be called syntactical rather than associative.

My major concern has been to examine afresh the nature of intellectual growth. The account has surely done violence to the richness of the subject. It seems to me that growth depends upon the emergence of two forms of competence. Children, as they grow, must acquire ways of representing the recurrent regularities in their environment, and they must transcend the momentary by developing ways of linking past to present to future—representation and integration. I have suggested that we can conceive of growth in both of these domains as the emergence of new technologies for the unlocking and amplification of human intellectual powers. Like the growth of technology, the growth of intellect is not smoothly monotonic. Rather, it moves forward in spurts as innovations are adopted. Most of the innovations are transmitted to the child in some prototypic form by agents of the culture: ways of responding, ways of looking and imaging, and most important, ways of translating what one has encountered into language.

I have relied heavily in this account on the successive emergence of action, image, and word as the vehicles of representation, a reliance based both upon our observations and upon modern readings of man's alloplastic evolution. Our attention has been directed largely to the transition between iconic and symbolic representation.

In children between 4 and 12 language comes to play an increasingly powerful role as an implement of knowing. Through simple experiments, I have tried to show how language shapes, augments, and even supercedes the child's earlier modes of processing information. Translation of experience into symbolic form, with its attendant means of achieving remote reference, transformation, and combination, opens up realms of intellectual possibility that are orders of magnitude beyond the most powerful image forming system.

What of the integration of intellectual activity into more coherent and interconnected acts? It has been the fashion, since Freud, to see delay of gratification as the principal dynamism behind this development—from primary process to secondary process, or from assimilation to accommodation, as Piaget would put it today. Without intending to question the depth of this insight, let me suggest that delay of immediate gratification, the ability to go beyond the moment, also depends upon techniques, and again they are techniques of representation. Perhaps representation exclusively by imagery and perceptual organization has built into it one basic operation that ties it to the immediate present. It is the operation of pointing—ostensiveness, as logicians call it. (This is not to say that highly evolved images do not go beyond immediate time and given place. Maps and flow charts are iconic in nature, but they are images that translate prior linguistic and mathematical renderings into a visual form.) Iconic representation, in the beginning, is build upon a perceptual organization that is tied to the "point-at-able" spatioqualitative properties of events. I have suggested that, for all its limitations, such representation is an achievement beyond the earlier stage where percepts are not autonomous of action. But so long as perceptual representation dominates, it is difficult to develop higher-order techniques for processing information by consecutive inferential steps that take one beyond what can be pointed at.

Once language becomes a medium for the translation of experience, there is a progressive release from immediacy. For language, as we have commented, has the new and powerful features of remoteness and arbitrariness: It permits productive, combinatorial operations in the *absence* of what is represented. With this achievement, the child can delay gratification by virtue of representing to himself what lies beyond the present, what other possibilities exist beyond the clue that is under his nose. The child may be *ready* for delay of gratification, but he is no more able to bring it off than somebody ready to build a house, save that he has not yet heard of tools.

The discussion leaves two obvious questions begging. What of the integration of behavior in organisms without language? And how does language become internalized as a vehicle for organizing experience? The first question has to be answered briefly and somewhat cryptically. Wherever integrated behavior has been studied—as in Lehrman's (1955) careful work on integrated instinctive patterns in the ringdove, it has turned out that a sustaining external stimulus was needed to keep the highly integrated behavior going. The best way to control behavior in subhuman species is to control the stimulus situation. Surely this is the lesson of Lashley's (1938) classic account of instinctive behavior. Where animal learning is concerned, particularly in the primates, there is, to be sure, considerable plasticity. But it too depends upon the development of complex forms of stimulus substitution and organization—as in Klüver's (1933) work on equivalence reactions in monkeys. If it should seem that I am urging that the growth of symbolic functioning links a unique set of powers to man's capacity, the appearance is quite as it should be.

As for how language becomes internalized as a program for ordering experience, I join those who despair for an answer. My speculation, for whatever it is worth, is that the process of internalization depends upon interaction with others, upon the need to develop corresponding categories and transformations for communal action. It is the need for cognitive coin that can be exchanged with those on whom we depend. What Roger Brown (1958) has called the Original Word Game ends up by being the Human Thinking Game.

If I have seemed to underemphasize the importance of inner capacities—for example, the capacity *for* language or *for* imagery—it is because I believe that this part of the story is given by the nature of man's evolution. What is significant about the growth of mind in the child is to what degree it depends not upon capacity but upon the unlocking of capacity by techniques that come from exposure to the specialized environment of a culture. Romantic clichés, like "the veneer of culture" or "natural man," are as misleading if not as damaging as the view that the course of human development can be viewed independently of the educational process we arrange to make that development possible.

REFERENCES

ABRAMYAN, L. A. Organization of the voluntary activity of the child with the help of verbal instruction. Unpublished diploma thesis, Moscow University, 1958. Cited by A. R. Luria, *The role of speech in the regulation of* *normal and abnormal behavior.* New York: Liveright, 1961.

BARKER, R. G. On the nature of the environment. Kurt Lewin Memorial Address presented at American Psychological Association, Philadelphia, September 1963.

BRAINE, M. D. On learning the grammatical order of words. *Psychol. Rev.,* 1963, **70**, 323–348.

BROWN, R. *Words and things.* Glencoe, Ill.: Free Press, 1958.

BRUNER, J. S., & KENNEY, HELEN. The development of the concepts of order and proportion in children. In J. S. Bruner, *Studies in cognitive growth.* New York: Wiley, in press.

CHOMSKY, N. *Syntactic structures.* S'Gravenhage, Netherlands: Mouton, 1957.

EMERSON, L. L. The effect of bodily orientation upon the young child's memory for position of objects. *Child Develpm.,* 1931, **2**, 125–142.

FRANK, FRANÇOISE. Perception and language in conservation. In J. S. Bruner, *Studies in cognitive growth.* New York: Wiley, in press.

HANFMANN, EUGENIA, RICKERS-OVSIANKINA, MARIA, & GOLDSTEIN, K. Case Lanuti: Extreme concretization of behavior due to damage of the brain cortex. *Psychol. Monogr.,* 1944, **57**(4, Whole No. 264).

HOCKETT, C. F. Animal "languages" and human language. In J. N. Spuhler, *The evolution of man's capacity for culture.* Detroit: Wayne State Univer. Press, 1959. Pp. 32–39.

HUTTENLOCHER, JANELLEN. The growth of conceptual strategies. In J. S. Bruner, *Studies in cognitive growth.* New York: Wiley, in press.

KLÜVER, H. *Behavior mechanisms in monkeys.* Chicago: Univer. Chicago Press, 1933.

LA BARRE, W. *The human animal.* Chicago: Univer. Chicago Press, 1954.

LASHLEY, K. S. Experimental analysis of instinctive behavior. *Psychol. Rev.,* 1938, **45**, 445–472.

LEHRMAN, D. S. The physiological basis of parental feeding behavior in the ring dove (*Streptopelia risoria*). *Behavior,* 1955, **7**, 241–286.

LURIA, A. R. *The role of speech in the regulation of normal and abnormal behavior.* New York: Liveright, 1961.

MANDLER, G. From association to structure. *Psychol. Rev.,* 1962, **69**, 415–427.

MARTSINOVSKAYA, E. N. Research into the reflective and regulatory role of the second signalling system of preschool age. Collected papers of the Department of Psychology, Moscow University, undated. Cited by A. R. Luria, *The role of speech in the regulation of normal and abnormal behavior.* New York: Liveright, 1961.

MILLER, G. A. Some psychological studies of grammar. *Amer. Psychologist,* 1962, **17**, 748–762.

MILLER, G. A., GALANTER, E., & PRIBRAM, K. H. *Plans and the structure of behavior.* New York: Holt, 1960.

MOSHER, F. A. Strategies for information gathering. Paper read at Eastern Psychological Association, Atlantic City, N. J., April 1962.

NAIR, PATRICIA. An experiment in conservation. In Center for Cognitive Studies, *Annual Report.* Cambridge, Mass.: Author, 1963.

OLVER, ROSE R. A developmental study of cognitive equivalence. Unpublished doctoral dissertation, Radcliffe College, 1961.

PIAGET, J. *The construction of reality in the child.* (Trans. by Margaret Cook) New York: Basic Books, 1954.

PIAGET, J., & INHELDER, BÄRBEL. *Le développement des quantités physiques chez l'enfant.* (2nd rev. ed.) Neuchâtel, Switzerland: Delachaux & Niestlé, 1962.

POTTER, MARY C. The growth of perceptual recognition. In J. S. Bruner, *Studies in cognitive growth.* New York: Wiley, in press.

RIGNEY, JOAN C. A developmental study of cognitive equivalence transformations and their use in the acquisition and processing of information. Unpublished honors thesis, Radcliffe College, Department of Social Relations, 1962.

VYGOTSKY, L. S. *Thought and language.* (Ed. & trans. by Eugenia Hanfmann & Gertrude Vakar) New York: Wiley, 1962.

WASHBURN, S. L., & HOWELL, F. C. Human evolution and culture. In S. Tax, *The evolution of man.* Vol. 2. Chicago: Univer. Chicago Press, 1960.

WEIR, RUTH H. *Language in the crib.* The Hague: Mouton, 1962.

WERNER, H. *Comparative psychology of mental development.* (Rev. ed.) Chicago: Follett, 1948.