GENETIC EPISTEMOLOGY

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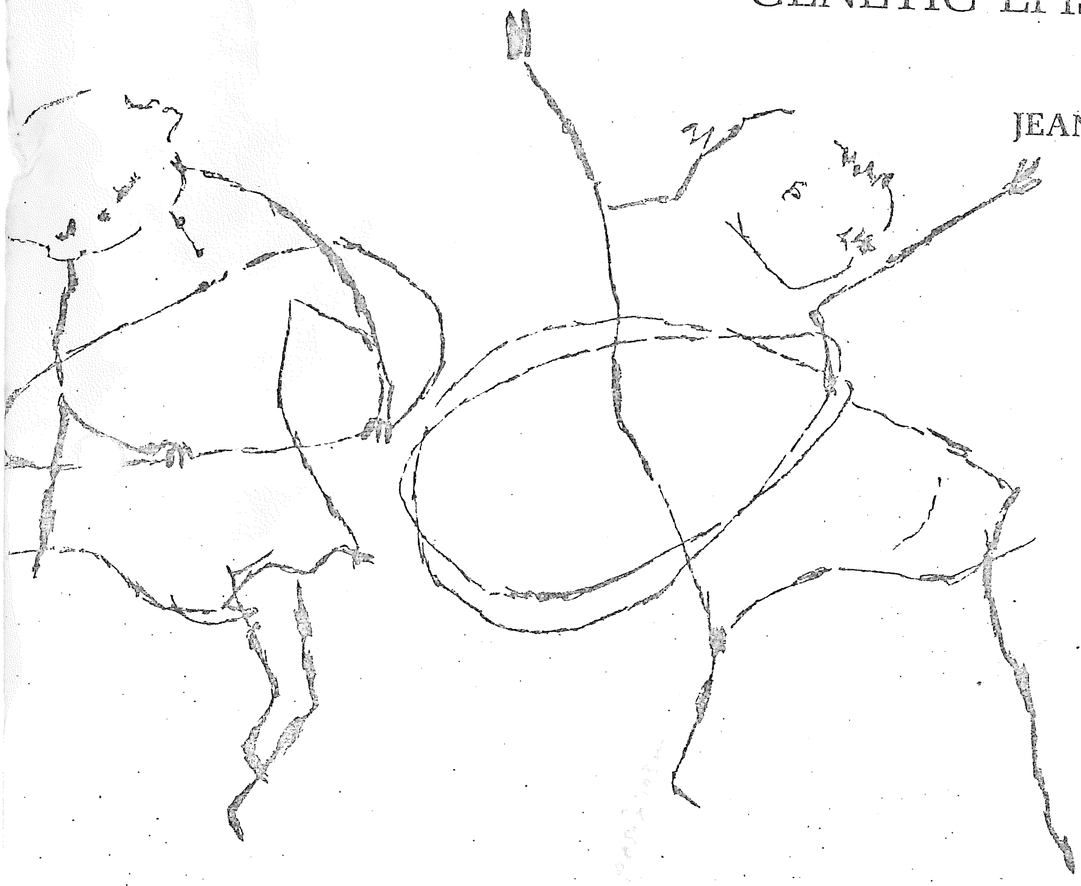

never taken psychology into account in their epistemology. They affirm that logical and mathematical reality are derived from language. Here it becomes necessary to look at factual findings, at the logical behavior in children before language develops.

In my discussion of the development of logical structures in children I should like to start by making a distinction between two complementary aspects of thought: the figurative and the operative. The figurative aspect is an imitation of states taken as momentary and static. In the cognitive area the figurative functions are, above all, perception, imitation, and mental imagery, which is interiorized imitation. The operative aspect deals not with states but with transformations from one state to another. It includes actions themselves, which transform objects or states, and intellectual operations, which are essentially systems of transformation. The figurative aspects are always subordinated to the operative. Any state can be understood only as the result of certain transformations, or as the point of departure for other transformations. To me, therefore, the essential aspect of thought is its operative aspect; I think that human knowledge is essentially active. To know is to assimilate reality into systems of transformation. To know is to transform reality in order

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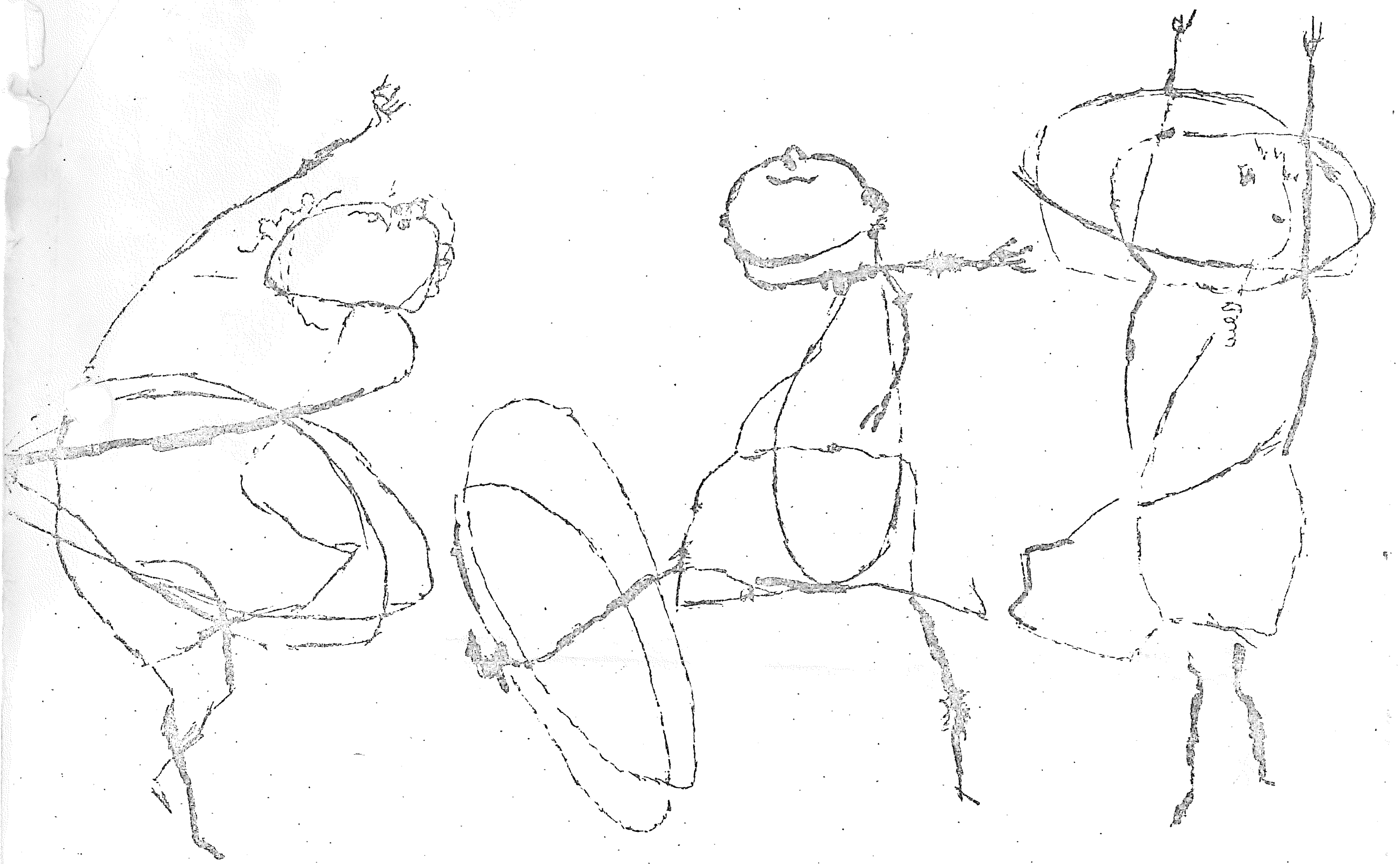


Genetic epistemology deals with the formation and meaning of knowledge and with the means by which the human mind goes from a lower level of knowledge to one that is judged to be higher. It is not for psychologists to decide what knowledge is lower or higher but rather to explain how the transition is made from one to the other. The nature of these transitions is a factual matter. They are historical, or psychological, or sometimes even biological.

The fundamental hypothesis of genetic epistemology is that there is a parallelism between the progress made in the logical and rational organization of knowledge and the corresponding formative psychological processes. With that hypothesis, the most fruitful, most obvious field of study would be the reconstituting of human history—the history of human thinking in prehistoric man. Unfortunately, we are not very well informed in the psychology of primitive man, but there are children all around us, and it is in studying children that we have the best chance of studying the development of logical knowledge, mathematical knowledge, physical knowledge, and so forth.

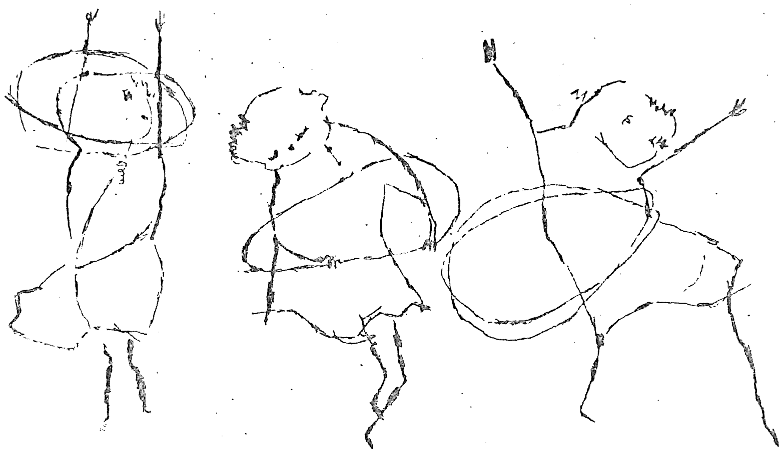
When we consider the nature of knowledge, the use of psychological data is indispensable. All epistemologists refer to psychological factors in their analyses but, for the most part, such references are speculative and not based on psychological research. Unfortunately for psychology, everybody thinks of himself as a psychologist. When an epistemologist needs to consider some psychological aspect of a problem, he does not refer to psychological research and he does not consult psychologists; he depends on his own reflections. He puts together certain ideas and relations within his own thinking. Logical positivists, in particular, have to understand how a certain state is brought about.

By virtue of this point of view, I find myself opposed to the view of knowledge as a passive copy of reality. In point of fact, this notion is based on a vicious circle: in order to make a copy you have to know the model you are copying, but the only way you know the model is by copying it. I believe, however, that knowing an object means acting upon it, constructing systems of transformations that can be carried out on or with this object. Knowing reality means constructing systems of transformations that correspond, more or less adequately, to reality. They are more or less isomorphic to transformations of reality. The transformational structures of which knowledge consists are not copies of the transformations in reality; they are simply possible isomorphic models among which experience can enable us to choose. Knowledge, then, is a system of transformations that become progressively adequate.

It is agreed that logical and mathematical structures are abstract, while physical knowledge, which is based on experience, is concrete. But let us ask what logical and mathematical knowledge is abstracted from. There are two possibilities. The first is that when we act upon an object our knowledge is derived from the object itself. A child, for instance, can heft objects in his hands and realize that they have different weights—that usually big things weigh more than little things, but that sometimes little things weigh more than big things. All this he finds out experientially, and his knowledge is abstracted from the objects themselves. This is the point of view of empiricism in general, and it is true for the most part in the case of experimental or empirical knowledge. But there is a second possibility: when we are acting upon an object we can also take into account the action itself, or operation, since the transformation can be carried out mentally. In this hypothesis, the abstraction is drawn not from the object acted upon, but from the action itself. It seems to me that this is the basis of logical and mathematical abstraction. Here I would like to give an example, one we have studied quite thoroughly with a lot of children. It was first suggested to me by a mathematician friend who quoted it as the point of departure of his interest in mathematics. When he was a small child he was counting pebbles one day; he lined them up in a row and counted them from left to right and got to ten. Then, just for fun, he counted them from right to left to see what he would get, and was astonished that he got ten again. He put the pebbles in a circle and counted them and once again there were ten. He went around the circle the other way and got ten again. And no matter how he put the pebbles, when he counted them they came to ten. He discovered here what is known in mathematics as commutativity; that is, the sum is independent of the order. But how did he discover this? Was commutativity a property of the pebbles? It is true that the pebbles, as it were, let it be done to themselves; he could not have done the same thing with drops of water. So in this sense there was a physical aspect to his knowledge. But the order was not in the pebbles; it was he, the subject, who put the pebbles in a line and then in a circle. Moreover, the sum was not in the pebbles themselves; it was he who united the pebbles. The knowledge that this future mathematician discovered that day was drawn, then, not from the physical properties of the pebbles, but from the actions that he carried out on them.

The first type of abstraction from objects I shall refer to as simple abstraction; the second type I shall call reflective abstraction, using this term in a double sense. "Reflective" here has a meaning in psychology in addition to the one it has in physics. In its physical sense reflection refers to such phenomena as the reflection of a beam of light off one surface onto another surface. In this sense the abstraction is a reflection from the level of action to the intellectual level of operation. On the other hand, reflection refers to the mental process of reflection; that is, at the level of thought a reorganization takes place.

I should like now to make a distinction between two types of actions. On the one hand, there are individual actions—like throwing, pushing, touching, rubbing. It is these actions that usually give rise to abstraction from the objects. This is the simple abstraction I discussed above. Reflective abstraction, however, is based not on individual actions but on coordinated action. Actions can be coordinated in different ways. They can be joined together (additive coordination); they can succeed each other in a temporal order (ordinal or sequential coordination); a correspondence between one action and another can be set up; or intersections among actions can be established. All these forms of coordination have parallels in logical structures, and it is this co-



rdination at the level of action that seems to me be at the basis of logical structures as they evelop later in thought. This, in fact, is my hypo-iesis: that the roots of logical thought are not be found in language alone, even though lan-iage coordinations are important. Rather, the ots of logic are to be found more generally in coordination of actions, which are the basis reflective abstraction.

This is only the beginning of a regressive anal-sis that could go much further. In genetic episte-iology, as in developmental psychology, there is ever an absolute beginning. We can never get ack to the point where we can say, here is the ery beginning of logical structures. As soon as e start talking about the general coordination f actions, we find ourselves going even further ito biology, which is not my intention here. I ist want to carry this regressive analysis back to s beginnings in psychology and emphasize again iat the formation of logical and mathematical ructures in human thinking cannot be explained y language alone, but has its roots in the general oordination of actions.

The decisive argument against the position that gical mathematical structures are derived unique- from linguistic forms is that in the course of y individual's intellectual development, logical iathematical structures exist *before* the appear-nce of language. Language appears somewhere bout the middle of the second year, but before ien, about the end of the first year or the begin-ing of the second, there is a sensory-motor intel-gence [illegible] is a practical intelligence having its wn logic—a logic of action. The actions that rm sensory-motor intelligence are capable of eing repeated and of being generalized. For ex-mple, a child who has learned to pull a blanket ward him in order to reach a toy that is on it then capable of pulling the blanket to reach iything else that may be placed on it. The action in also be generalized so that he learns to pull string to reach what is attached to the end of e string, or so that he can use a stick to move distant object.

Whatever is repeatable and generalizable in an tion is what I have called a scheme, and I main-in that there is a logic of schemes. Any given heme in itself does not have a logical compo-nt, but schemes can be coordinated with one other, thus implying the general coordination of actions. These coordinations form a logic of actions that are the point of departure for the logical mathematical structures. For example, a scheme can consist of subschemes or subsystems. If I move a stick to move an object, there is within that scheme one subscheme of the relation between the hand and the stick, a second subscheme of the relation between the stick and the object, a third subscheme of the relation between the object and its position in space, and so on. This is the beginning of the relation of inclusion. The subschemes are included within the total scheme, just as in the logical mathematical structure of classification subclasses are included within the total class. At a later stage this relation of class inclusion gives rise to concepts. At the sensory-motor stage a scheme is a sort of practical concept.

Another type of logic involved in the coordination of schemes is the logic of order: for instance, to achieve an end we have to go through certain means. There is thus an order between the means and the goal. Once again, it is practical-order relations of this sort that are the basis of the later logical mathematical structures of order. There is also a primitive type of one-to-one correspondence. When an infant imitates a model, there is a correspondence between the model on the one hand and his imitation on the other. Even when he imitates himself, that is, when he repeats an action, there is a correspondence between the action as carried out one time and the action as carried out the next.

In other words, we find in sensory-motor intelligence a certain logic of inclusion, a certain logic of ordering, and a certain logic of correspondence, which I maintain are the foundations for logical mathematical structures. They are certainly not operations, but they are the beginnings of what will later become operations. We can also find in this sensory-motor intelligence the beginnings of two essential characteristics of operations, namely, a form of conservation and a form of reversibility.

The conservation characteristic of sensory-motor intelligence takes the form of the notion of the permanence of an object. This notion does not exist until near the end of the infant's first year. If a seven- or eight-month-old reaches for an object that interests him and we suddenly put a screen between him and the object, not only has the object disappeared but it also is no longer accessible. He will withdraw his hand and make no attempt to push aside the screen, even if it is as delicate a screen as a handkerchief. Near the end of the first year, however, he will push aside the screen and continue to reach for the object. He will even be able to keep track of a successive number of changes of position. If the object is put in a box and the box is put behind a chair, for instance, the child will be able to follow these successive changes of position. This notion of the permanence of an object, then, is the sensory-motor equivalent of the notions of conservation that develop later at the operational level.

Similarly, we can see the beginnings of reversibility in the understanding of spatial positions and changes of position. At the beginning of the second year children have a practical notion of space which geometers call the group of displacements, that is, the understanding that a movement in one direction can be canceled by a movement in another direction—that a point in space can be reached by one of a number of different routes. This, of course, is the detour behavior that psychologists have studied in such detail in chimpanzees and infants.

This, again, is practical intelligence. It is not at the level of thought, and it is not at all representational, but the child can act in space with this intelligence. Furthermore, this organization exists as early as the second half of the first year, before any use of language for expression. So much for my first argument.

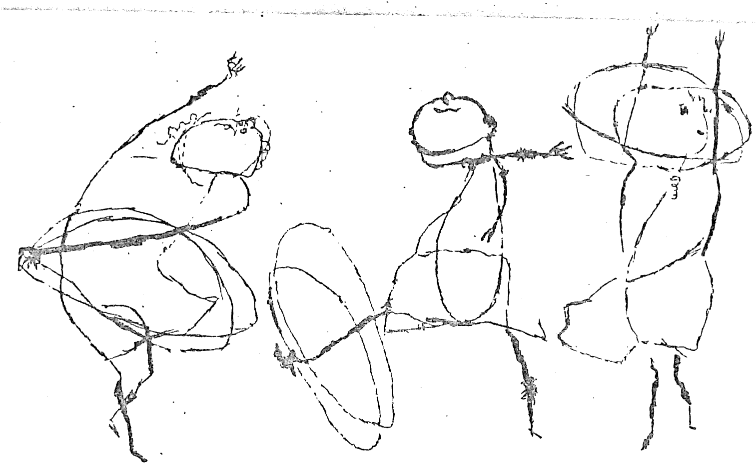
My second argument deals with children whose thinking is logical but who do not have language available to them, namely, the deaf and dumb. Before I discuss the experimental findings on intelligence in deaf and dumb children, I should like to discuss briefly the nature of representation. Between the ages of about 18 months and seven or eight years, when the operations appear, the practical logic of sensory-motor intelligence goes through a period of being internalized, of taking shape in thought at the level of representation rather than in the carrying out of actions only. I should like to insist here on a point that is too often forgotten: there are many forms of representation. Actions can be represented in a number of different ways, of which language is only one. It is merely one aspect of the general function that some call the symbolic function. I prefer to use the linguistics term and call it the semiotic function. This is the ability to represent something by a sign or a symbol or another object. In addition to language, the semiotic function includes gestures, either idiosyncratic or, as in the case of the deaf and dumb language, systematized. It includes deferred imitation, that is, imitation that takes place when the model is no longer present. It includes drawing, painting, modeling, and mental imagery, or internalized imitation. In all these there is a signifier representing that which is signified, and all these ways are used by individual children in their passage from intelligence that is acted out to intelligence that is thought. Language is but one among many aspects of the semiotic function, even though it is in most instances the most important.

This position is confirmed by the fact that in deaf and dumb children we find thought without language and logical structures without language. Professor Pierre Oleron in France has done interesting work in this area. In the United States I should like to mention especially the work of Hans Furth and his excellent book, *Thinking Without Language*. Furth finds a certain delay in the development of logical structures in deaf and dumb children as compared with normal children. This is not surprising since the social stimulation of the former is so limited, but apart from this delay the development of the logical structures is similar. He finds classifications of the sort discussed before; he finds correspondence; he finds numerical quantity; and he finds the representation of space. In short, there is well-developed logical thinking in these children even without language.

Another interesting point is that although deaf and dumb children are delayed compared to normal children, they are delayed much less than children who have been blind from birth. Blind infants have the great disadvantage of not being able to make the same coordinations in space that normal children are capable of during the first year or two, so that the development of sensory-motor intelligence and the coordination of actions at this level are seriously impeded in blind children. For this reason we find that there are

:en greater delays in their development at the ·vel of representational thinking and that lan-ıage is not sufficient to compensate for the :ficiency in the coordination of actions. The ·lay is made up ultimately, of course, but it is ;nificant and considerably more than the delay the development of logic in deaf and dumb ildren.

My final argument will be based on the work of .dame Hermine Sinclair, who studied the rela-ns between operational and linguistic levels in ldren between the ages of five and eight years. ne. Sinclair was a linguist before coming to ıdy psychology in Geneva; at her first contact ith our work she was convinced of the logical ɔsitivist position, that is, that the operational vel of children simply reflected their linguistic vel. I suggested to her that she study this ques-ɔn, sinc had never been studied closely, and e what relations existed between the two. As a sult, Mme. Sinclair performed the following ex-riment: first she established two groups of ildren. One group consisted of conservers—ose who realized that when liquid was poured ɔm a glass of one shape into a glass of another ape the quantity did not change, in spite of pearances. The other group consisted of non-nservers—those who judged the quantity of liq-d according to its appearance and not according any correlation between height and width of ntainer, or reasoning in terms of the fact that no had been added or taken away. Then Mme. nclair proceeded to study the language of each oup by giving them very simple objects to de-ibe. Usually she presented the objects in pairs that the children could describe them by com-ing th as well as citing their individual char-eristics. (She gave them, for instance, pencils different widths and lengths.) She found notice-e differences in the language used to describe se objects according to whether the child was conserver or a nonconserver. Nonconservers ded to describe objects in terms that linguists l scalers. That is, they would describe one ob-t at a time and one characteristic at a time—ıat pencil is long"; "that pencil is fat"; "it is rt"; etc. The conservers, on the other hand, d what linguists call vectors. They would keep nind both objects at once and more than one racteristic at once. They would say, "This pen-is longer than that one, but that one is fatter n this one"—sentences of that sort.



So far the experiment seemed to show a relation between the operational level and the linguistic level, but it did not indicate in what sense the influence is exercised. Is the linguistic level influencing the operational level, or is the operational level influencing the linguistic progress? To find the answer Mme. Sinclair went on to another aspect of the experiment. She gave linguistic training to the nonconserving group. Through classical learning-theory methods she taught these children to describe the objects in the same terms that the conservers used. Then she examined them again to see whether this training had affected their operational level. (She did this experiment in several areas of operations, not only for conservation but also for seriation and other areas.) In every case she found that there was only minimal progress after the linguistic training. Only 10 per cent of the children advanced from one substage to another. This is such a small percentage that it leads one to wonder whether these children were not already at an intermediate phase and right on the threshold of the next substage. Mme. Sinclair's conclusion, on the basis of these experiments, is that intellectual operations appear to give rise to linguistic progress, not vice versa.

I would like to go on now to examine the type of thinking that children are capable of in what I call the preoperational stage, that is, ages four, five, and six, before the development of logical operations. Although logical structures are not fully developed at this stage, we can find there what I once called "articulated intuitions," but now, after a good deal more research, I would call, very literally, "semi-logic." That is, the thought of children of these ages is characterized by half logic, or operations that lack reversibility; they work only in one direction. This logic consists of functions as described by mathematicians: y=(f)x. A function in this sense represents an ordered couple or an application, but one that moves always in one direction. This kind of thinking leads to the discovery of dependent relations and co-variations: the correlation of variations in one object with variations in another.

The remarkable thing about these functions is that they do not lead to conservation. Here is one example: a piece of string, attached to a small spring, goes out horizontally, around a pivot, and hangs down vertically. Now, when we put a weight, or increase the weight, on the end of the string, the string is pulled so that the part hanging vertically is lengthened compared to the horizontal part. Five-year-olds are perfectly capable of grasping that with the greater weight the vertical part is longer and the horizontal is shorter, and further that when the vertical part becomes shorter the horizontal becomes longer. But they do not thereby become conservationists. For them, the sum of the vertical and horizontal parts does not stay the same.

Here is another example of a function in the sense of an application. Children are given a number of cards, on each of which there is a white part and a red part, and they are given cut-outs of different shapes. Their task to to find the cut-out that will cover up the red part on the card. It need not correspond exactly, but it must cover the card so that no red part shows. The interesting thing is that these children understand the relation many-to-one—they realize that a number of the different cut-out shapes can cover the red. Nevertheless, they do not go on from there to construct a classification system based on the relation of one-to-many. Once again, it is a case of half of a logical structure.

More generally, the reason why functions are so interesting is that they show us clearly the importance of relations of order in preoperational thinking. Many relations that are metric for us are simply ordinal for children: measure does not enter into their judgments. A good illustration is the conservation of length. If two sticks are the same length when they are side by side, we would judge them to be the same length when they are separated because we would take into account both ends and realize that the important thing is the distance between the left and right ends in each case. Preoperational children, however, do not base their judgments on the order of the end points. If they are looking at one end of the stick their judgments of length are based on which one goes further in that direction.

Another characteristic of semi-logic is the notion of identity, which precedes the notion of conservation. We have already seen that there is a certain notion of identity in sensory-motor intelligence; a child realizes that an object has a certain permanence. This is not conservation in the sense that we have been using the term, since the object does not change its form in any way, but only its position. Yet, it is identity, and one of the starting points for the later notion of conservation. In our studies of the notion of identity in preoperational thinking from the age of about four years, we have found that it is highly variable. What it means for something to preserve its identity changes according to the age of the child and according to the situation in which the problem is presented.

The first thing to keep in mind is that identity is a qualitative, not a quantitative notion. For instance, a preoperational child who will maintain that the quantity of water changes according to the shape of its container, will nonetheless affirm that it is the same water—only the quantity has changed. My colleague, Jerome Bruner, thinks that a notion of the principle of identity is sufficient as a foundation for the notion of conservation. But I find this position questionable. To have the principle of identity one has only to distinguish between that which changes in a given transformation and that which does not change. In the case of the pouring of liquids, children need only make a distinction between the form and the substance. But more than that is required in the notion of conservation. Quantification is rather more complex, especially since the most primitive quantitative notions are the ordinal ones, which are not adequate in all cases of quantitative comparison. It is not until children also develop the operation of compensation and reversibility that the quantitative notion of conservation is established.

Now I would like to go on to some new examples of how the notion of identity changes with development. We have done several different experiments and found a first level where identity is semi-individual and semi-generic. A child will believe that objects are identical to the extent that one can do the same things with them. For instance, a collection of beads on a table is recognized as being the same as the beads in the form of a necklace, because one can take them apart and make a pile of them or string them together into a necklace. Similarly, a piece of wire in the shape of an arc is recognized as being the same when it is straight, because it can be bent into an arc or pulled into a straight line. A little later a child becomes more lemanding in his criteria for identity, however. Then it is no longer sufficient that the object be assimilated to a certain scheme. The identity becomes more individualized. At this stage he will say that it is no longer the same piece of wire when it is in the shape of an arc, because it no longer ias the same form.

One interesting experiment illustrating this grew out of another experiment. Children were ordering juares according to size, and in the course of this ictivity one child put a square on a corner instead of along the edge, and then he rejected it, saying hat it was no longer a square. We then started nother experiment in which we investigated this iore closely, presenting a cut-out square in different positions and asking questions like the following: Is it the same square? Is it still a square? s it th same piece of cardboard? Are the sides till the same length? Are the diagonals still the ime length? We put these questions, of course, in rms that made sense to the children we were nterviewing. We found that until the age of about seven the children denied the identity. They insisted that it was no longer the same square, that t was no longer a square at all, that the sides were io longer the same length, and so on.

Similar experiments are possible in the area of erception. We are all familiar with the phenomnon of apparent or stroboscopic motion. One bject appears and disappears, and as it disappears, nother appears, and as the second object disppears, the first appears again. If this is done at he right speed it looks as if the same object is oving back and forth between two positions. It ccurred to me that it would be interesting to study ie phenomenon of identity through the phenomnon c oboscopic motion by having one of the bjects a circle and the other a square—so when ie object moves to one side it looks as if it is ecoming a circle, and when it moves to the other de it looks as if it is becoming a square. It looks ke a single object that is changing its shape as changes its position. I should point out that it much easier for children to see this apparent iotion than it is for adults. But the interesting ing in our experiment is that despite their facility seeing stroboscopic motion, the children tend deny the identity of the object. They will say at it is a circle until it gets almost to the other de, and then it becomes a square; or, that it is no longer the same object—one takes the place of the other. Adults, on the other hand, see a circle that turns into a square, and a square that turns into a circle. They find it strange, but nonetheless, that is what they see. It is the same object changing its shape. According to this experiment, then, the notion of identity increases with age. And this is only one of many experiments in which we have found similar results.

One last experiment I would like to mention was carried out by Boyat on the growth of the plant. Boyat started by experimenting with the growth of a bean plant, but that took too long, so he turned to a chemical solution that grows in a few minutes into an arborescent shape that looks something like seaweed. As a child watches this plant grow he is periodically asked to draw it; then, with his drawings as reminders, he is asked if at the various points in its growth it is still the same plant. We use whatever term the child uses to refer to it—a plant, seaweed, macaroni, or whatever. Then we ask him to draw himself when he was a baby, when he was a little bigger, a little bigger than that, and as he is now. And we ask the same questions as to whether all these drawings are of the same person, whether it is always he. At a relatively young age, a child will deny that the same plant is represented in his various drawings. In referring to the drawings of himself, however, he will likely say that it is the same person. Then if we go back to the drawings of the plant, some children will be influenced by their thoughts on their drawings of themselves and say that now they realize that it is the same plant. But others will continue to deny that it is the same plant, maintaining that it has changed too much, that it is a different plant now. Here, then, is an amusing experiment that shows that the changes that take place within the logical thinking of children as they grow older affect the notion of identity itself. Even identity changes in this field of continual transformation and change.