THE PERIOD OF CONCRETE OPERATIONS (7 to 11 years)

The period of concrete operations is characterised by an orderliness of thinking which gives rise to the ability to decenter and recognize transformations, awareness that some transformations are reversible, and of course a grasp of the concept of conservation. Flavell contrasts it with the preceding periods as follows.

...the preoperational child differs profoundly from the sensory- motor infant by virtue of the fact that he operates on a wholly new plane of reality, the plane of representation as opposed to direct action. Since the concrete operational child also operates on the same plane (as the preoperational child), the question arises: what are the differences between the two?....It is simply that the older child seems to have at his command a coherent and integrated cognitive system with which he organises and manipulates the world around him .

The integrated cognitive system of which Flavell writes is an organized network of operations. What kind of mental event is an operation? It is an act of representation, such as adding, subtracting, multiplying, or dividing. Piaget has elaborately detailed nine different groupings of logical operations which define the system of concrete operations.

The accomplishments of the concrete operational stage are many. Besides the ability to conserve the child has lost much egocentrism and has gained in sensitivity to contradictions inherent in his or her own thought. The child's ability to represent the world symbolically is greatly advanced. Given the accomplishments of children at this age, one may reasonably ask, What sorts of operations can concrete operational children not perform? The answer is intriguing.

Although concrete operational children understand relationships among specific events in the environment, they are unable to produce formal, abstract hypotheses. They cannot imagine possible events that are not also real events, and thus they cannot solve problems that involve formal abstractions. As an example, consider Archimedes' law of floating bodies. This principle, which is a formal abstraction, states that an object will float in water if its density (weight per unit) is less than that of water. This law means that, if two objects are of equal weight, the smaller object is more likely to sink than the larger. This fact can give rise to an experimental test. Specifically, a child is given a bucket of water and several different small objects, some of which will float and some of which will sink when placed in the liquid. The child's job is to classify the objects in terms of whether they will float or sink. And to look for a rule that will tie the findings together.

Concrete operational children will say such things as " an object sinks because it is iron " "because it is heavy." And so on. They will be troubled and confused, though, by the dilemmas created by such rules (i.e., a rock sinks). In contrast, children who have reached the stage of formal operations appear to be able to abstract the appropriate statement. The phenomenon is illustrated by Piaget's description of one child who, at age twelve years, six months, comes close to a solution, saying in reference to a penny, that "it sinks because it is small, it isn't stretched enough...you would have to have something larger to stay at the surface, something of the same weight and which would have a greater extension".

Concrete operational children are bound up with the world as it is, and they cannot get any further until they begin to delineate all possible explanations at the outset of considering a problem. Only then do they try to discover, systematically, which of the explanations really applies. This advanced way of thinking, in which what occurs in reality is seen as just one among many possible alternatives, is part of what makes the thinking of the formal operational child more powerful than it has been at any earlier period.

Over-generalizations

THE PERIOD OF FORMAL OPERATIONS (11 through Adulthood)

Beginning with preadolescence, people begin to display the ability to engage in formal reasoning on an abstract level. They can draw hypotheses from their observations, imagine hypothetical as wall as real events, and deduce or induce principles regarding the world around them. Efforts to solve the pendulum problem **exemplify this final stage of** cognitive development.

The pendulum problem

Inhelder and Piaget (1958) have used the following setup to explore formal operational thought. The subject is presented with a pendulum consisting of an object hanging from a string. He or she is permitted to vary the length of the string, change the weight of the suspended object, alter the height from which the pendulum is released, and push the pendulum with varying degrees of force. The problem that must be solved is a classical one in physics: to discover and state which if these factors alone or in combination will influence how quickly the pendulum swings. (In fact, length of the string is the critical variable. The shorter it is, the faster the pendulum swings.) Because the experimenter plays nondirective role, the way in which the problem is solved tells us much about the cognitive operations of the performer.

Concrete operational children approach the problem unsystematically and soon fail or give up because their chaotic approach leaves them without any real clue to the answer. Formal operational children, in contrast, handle the problem very systematically. First, the adolescent envisages all the possible factors and combinations of factors that could influence the speed of the pendulum: string length, weight, height of release, force, length and height, length and weight and height, and so on. This analysis of possibilities can be exhaustive, and the formal operational child can cast the possibilities into the form of propositions which function as hypotheses. Finally, these hypotheses are put to empirical test. To construct a valid test of each hypothesis the child varies one dimension, such as length of string, while holding all other dimensions constant. For example, a 100-gram weight with a long string will be compared with a 100-gram weight with a short string. The formal operational thinker realizes that an experiment would yield inconclusive results if both weight and string length were varied together because he or she would be unable to deduce which factor produced the difference in speed. Inhelder and Piaget give an exemplary case of a fifteen-year old who

... after having selected 100 grams with a long string and a medium length string, then 20 grams with a long and short string, and finally 200 grams with a long and short, concludes : "It's the length of the string that makes it go faster or slower ; the weight doesn't play any role." She discounts likewise the height of the drop and the force of her push.

As with the conservation problems, the question is, can children below the age of formal operations learn to master formal operations problems? a series of studies by Siegler and his colleagues (Siegler, 1975 ; Siegler and Atlas, 1975 ; Siegler and Liebert, 1975 ; Siegler Liebert, and Liebert, 1973) indicates that they can. In one of these studies, Siegler, Liebert and Liebert attempted to teach the pendulum problem to ten-and eleven-year-olds. The instructional procedure included definitions of key scientific concepts, application of these concepts to particular problems and demonstration of the use of precise measuring instruments. Roughly 70 percent of the children who were provided such instruction mastered the pendulum problem, compared with less than 10 percent of the uninstructed children. The other studies in the series also testify to the ability of concrete-operations-agreed children to learn formal operations concepts, although, in accord with Inhelder and Piaget's findings, these children rarely solve the problems without instruction.. In fact, the intellectual sophistication acquired during the formal operations period seems to be a prerequisite for all scientific thinking. It is with this understanding of the scientific method according to Piaget, that the basic development of intellectual processes arrives at its most advanced state.

THE HIGHER MENTAL PROCESSES

The course of cognitive development charted by Piaget is accompanied by the concurrent development of several important mental processes which are required for adaptive and intelligent behavior. In this section we will consider mental representation, concept formation, reasoning, and selective attention and memory.

MENTAL REPRESENTATION

Throughout the foregoing discussion of Piaget's theory we saw that the process of mental representation of the world plays a central role in cognitive development, but we have not yet examined the process in any detail.

According to Piaget, a major advance in the child's ability to represent events mentally occurs at about two years of age, corresponding closely with the onset of the pre operational period. At this time the child begins to distinguish what Piaget calls signifiers (internal symbols and signs) from significates (the actual object, events, and actions to which signifiers refer). In the following passage, Piaget describes an incident in which his daughter Lucienne, two years old, symbolizes an act not yet performed:

...I put the chain inside an empty matchbox (where the matches belong), then closed the box leaving an opening of 10mm. Lucienne begins by turning the whole thing over, then tries to grasp the chain through the opening. Not succeeding, she simply puts her index finger into the slit and so succeeds in getting out a small fragment of the chain; she then pulls it until she has completely solved the problem.

Here begins the experiment which we want to emphasize. I put The Higher Mental chain back into the box and reduced the opening to 3mm. It is understood that Lucienne is not aware of the functioning of the opening and closing of the matchbox and has not seen me prepare the experiment. She only possesses the two preceding schemate: turning the box over in order to empty it of its contents, and sliding her finger into the slit to make the chain come out. It is of course this last procedure that she tries first; she puts her finger inside and gropes to reach the chain, but fails completely. A pause follows during which Lucienne manifests a very curious reaction bearing witness not only to the fact she tries to think out the genesis of representations. Lusienne mimics the widening of the slit.

She looks at the slit with great attention; then, se several times in succession, she opens and shuts her mouth, at first slightly, then wider and wider! Apparently Lucien understands the existence of cavity adjacent to the slit and wishes to enlarge the cavity. The attempt at representation which she thus furnishes is expressed physically, that is to say, due to inability to think out the situation in words or clear visual images she uses a simple motor indication as "signifier" or symbol. Lucienne, by opening her mouth thus expresses, or even reflects her desire to enlarge the opening of the box. This schema of imitation, with she is familiar, constitutes for her the means of thinking out the situation. There is doubtless added to it an element of magic-phenomenalistic causality or efficacy, just as she often uses imitation to act upon persons and make them reproduce their interesting movements, so also it is probable that act of opening her mouth in front of the slit to be enlarged implies some underlying idea of efficacy.

Soon after....Lucien unhesitatingly puts her finger in the slit and instead of trying as before to reach the chain, she pulls so as to enlarge the opening. She succeeds and grasps the chain. (Cited in Fluvial, 1963,pp. 119-120, italics added).

Of considerable importance for our understanding of the development of mental representation is Piaget's distinction between two kinds of signifiers: symbols and signs., Symbols correspond in a relatively private way to the events that they represent and somewhat resemble them physically (e.g., Lucienne's opening and closing her mouth).Signs, on the other hand, bear no obvious resemblance to the events they represent; their meaning are arbitrary, but they are shared by other members of the environment (e. g., formal language).

Piaget argues that representational thought does not have its beginnings in social language, but rather in private symbols which form the basis for later acquisition of language. Language development, which we will discuss in detail in Chapter 9, is dependent upon the usage of certain paralinguistic symbols; later, in turn, language fosters further development of private symbols. This basic view, that early mental representation does not rely heavily on language, lies at the theory of Jerome S. Bruner, which we will see next time.