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ABSTRACT

Twenty-six children ranging in age from 6 to 12 years whose tested IQ's were over 160 were tested on three Piagetian tasks of advanced concrete operations and two tests of formal operations. All children passed all concrete operations problems, but only four of the oldest boys passed the formal operations tasks. Findings are discussed in terms of possible relationships between Piagetian and psychometric measures of intelligence. (SBT)

Concrete and Formal Operations in Very Bright (IQ > 160) Six to Eleven-Year-Olds[1]

by

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The relationship between psychometric notions of intelligence (i.e., as measured by IQ tests) and the Piagetian operations of intelligence (e.g., Inhelder & Piaget, 1969) has become a topic of some interest. A symposium, Measurement and Piaget, has been devoted to the topic (Greene, Ford, & Flamer, 1971) and several attempts at "psychometrizing" Piaget have appeared (e.g., Tuddenham, 1970).

Three hypotheses have been suggested concerning the nature of this relationship. Keating (1973) has proposed that Piagetian tests measure roughly the same thing as do more traditional tests, though possibly less well and certainly with less efficiency. Elkind (1970) and others have proposed that the Piagetian and psychometric traditions approach essentially the same material (i.e., intellectual development), but from different perspectives; and the resulting measures thus possess characteristic differences. Finally, some writers working usually from factor analytic data (e.g., Kohlberg & DeVries, 1973; Stephens, et al., 1972) have argued that Piagetian and traditional intelligence tests measure fundamentally different things.

Abstract

Twenty-six children ranging in age from six to 11 years whose tested IQ's were in excess of 160 were tested on three Piagetian tests of advanced concrete operations and two tests of formal operations. All children passed all concrete operations problems, but only four of the oldest boys passed the formal operations tasks. The findings support the reality of Piaget's stage structures, but suggest that how quickly tasks within a stage are mastered (horizontal décalage) is a function of intelligence in the psychometric sense.

A fourth possibility is that Piagetian measures and IQ tests measure the same things _within_ a Piagetian stage, but measure unrelated things _across_ stages. Such a conclusion would follow from two assumptions: (1) the major Piagetian stages have biological reality and are essentially under maturational control; and (2) once the capacity for the operations specified by the stage models is obtained, how quickly the operations are extended to various aspects of the world is a function of intelligence in the IQ sense (cf. Lovell & Shields, 1967).

A quick test of the feasibility of this hypothesis and its two underlying assumptions would be to test very bright children from approximately 6 to 11 years of age with a variety of concrete and formal operational tasks. If the two assumptions contained within this hypothesis are correct, very bright children within this age range should master all the difficult concrete operational tasks, but should show no particular precocity in formal operations.

Method

Subjects. Twenty-five children ranging in age from 6;2 (6 years, 2 months) to 11;1, and one additional girl 12;0, all with IQ's over 160, were studied. Twenty-five subjects were located through a program operated by the Anne Arundel County, Maryland, school system and the remaining child, a boy 6;2, through a guidance counselor in Baltimore County, Maryland. IQ's were determined by the Slosson Intelligence Test which correlates above .9 with the Stanford-Binet (Slosson, 1961). Eight girls and 18 boys were included in the sample. The sample was all white and observations of the home situations suggested a wide range of economic circumstances.

Procedure. Children were tested individually in their homes by the experimenter and an assistant. Five test situations were employed with some variations in technique for children of differing ages and responsiveness to the experimenter. The five situations were:

1. Differentiation of distance traveled from end point: The straight and crooked road problem described by Piaget (1971); Subjects were asked to make a car on the crooked road go "just as far" as a car which was preset at a certain point on the straight road. After moving the car the child was asked questions concerning the distance traveled as opposed to the left-right displacement. Further questioning centered on the time required to reach various end points on the crooked as opposed to the straight road. Finally, the child was asked how he could measure the relative distances involved.

2. Conservation of volume: Two beakers of water and two plasticine balls were employed. The critical question in the procedure was whether the ball of clay would raise the level of

water the same height after it was torn into pieces. Subjects' answers were scored for four criteria of sophistication: (a) correctness (the water would come up to the same height); (b) reasons (Does the child justify his answer on an acceptable basis: Piagetian notions of compensation, reversibility, or identity?); (c) degree of confidence in the face of contradictory arguments from the experimenter; and (d) any reference to the weight of the ball as opposed to its volume.

3. Conservation of internal volume: Piaget's (see Flavell, 1963; Lovell & Ogilvie, 1961) problem of building houses of constant volume on islands of different surface areas was employed. A solid 3 x 3 x 4 inch cube was placed on one "island" and the child was provided with a pile of cubes measuring one inch on a side. Subjects were asked to build houses with "just the same amount of room" on three islands with areas of 3 x 4 inches, 2 x 4 inches, and 1 x 4 inches. On completion of each construction the child was asked to justify his response. Any measurement operations were noted and whether the child justified his answers with reference to the number of cubes or the multiplication of the three dimensions.

4. Inhelder and Piaget's (1958) problem of the law of floating bodies. A collection of varied objects and a large beaker of water were presented. The subject was first asked to classify the objects into those that would float and those which would not. After classi-

fication and correction by empirical test, the subject was asked to formulate a general law. Throughout the process, the experimenter intervened to point out contradictions.

5. Inhelder and Piaget's (1958) balance problem. The apparatus consisted of a balance constructed from an 18 inch wooden rule mounted on a frame with holes at each inch mark, and a set of small plastic weights. The child was asked to balance a number of specific combinations of weights and distances and asked to formulate the general rule for balancing the moments of force. Care was taken to distinguish between empirical strategies and the theoretical rule that was sought.

Each protocol was scored independently by a student research assistant and the investigator. Each concrete operational problem (1-3) was scored for the correctness of the answer and the suitability of the reasons given. In addition, the conservation of volume problem was scored for the additional criteria listed above. The formal operations problems (4,5) were analyzed for an acceptable abstract formulation as opposed to an empirical approach.

Results

Results for the three tests of concrete operations were simple and unequivocal. All subjects passed all three tests, and with two exceptions, gave acceptable reasons. There was no disagreement between judges on these points. In order to conserve space only the conservation of volume problem will be discussed in detail.

The basic question in the conservation of volume problem is whether a ball of clay will displace the same amount of water after a shape transformation. All 26 subjects said that it would. When asked why this was so, the majority of subjects gave an acceptable reason. Fifteen used identity explanations ("You haven't added any clay," "It's still the same clay"); 11 gave compensation reasons ("There are more pieces, but they are smaller"); and seven cited reversibility ("You could roll it back into a ball and it would be just as big as before"). The total here exceeds 26 since some subjects gave more than one reason. Only two subjects, one boy 11;0 and one girl 12;0 failed to give one of these reasons, though both contended there was the same amount of clay.

When the experimenter attempted to contradict the subjects' conclusions ("Look, all these pieces are sure to push the water up higher"), most children steadfastly held to their convictions. Fifteen of 26 subjects showed absolutely no evidence of believing the counterargument. The remaining 11 were willing to consider the point and showed varying degrees of vacillation, though when asked for a final prediction all held to their original answer. Indications of being swayed by the counterargument were interestingly scattered across the age range and were more frequent among girls (5/8) than boys (6/18), though the difference in proportions is not statistically significant ($z=1.37$).

Fourteen subjects referred to the weight of the clay balls as responsible for pushing up the water level, and the majority of subjects first suggested weighing the balls of clay to determine "if they are the same size." This finding supports the general finding that weight is a simpler concept than volume and may be preferred even by children who are capable of dealing with volume.

Analysis of the formal operations problems was more difficult than the concrete since there are many ways to phrase an appropriate formulation. Lack of objective unequivocal criteria for classifying answers may be one reason for the general dearth of research on formal operations. Given these limitations, there were four subjects who gave formulations to both formal operations problems that two independent judges considered acceptable. All were boys, 10;7 or older. Only five other subjects were considered passing or marginal on one problem by one judge. With one exception these subjects were all above 10;0; two were girls and three were boys. The exceptional young subject was a boy 8;10 who was rated as passing the balance problem by one judge and not passing by the other. It should be noted that the analysis of the formal operations problems required a total of 52 judgments (26 subjects X 2 problems) and five of these produced disagreement between the two judges.

Discussion

The data from the present study lend some credence to the hypothesis suggested above relating psychometric to Piagetian measures of intelligence. The most striking fact is the success of bright young children on concrete operations problems that are difficult for older average children. The percentage of 12-year-olds passing the conservation of volume problem has been estimated from 25% to 40% (Goodnow & Bethon, 1966; Lovell & Ogilvie, 1961). All 26 subjects 11 and under in the present sample passed this test. Assuming that the probability of passing the task is .5 and using only the 11 subjects nine or younger in the present sample--both conservative assumptions--finding a sample in which 100% pass the task is highly unlikely ($z=3.3$). Similarly the conservation of three dimensional space should be difficult for such young subjects even though the normative data are less clear (Flavell, 1963; Lovell & Ogilvie, 1961). Success on the distance problem is less surprising though some of the younger subjects would be expected to fail. Thus, half the hypothesis is clearly supported. Once concrete operations are attained, bright subjects are very quick to generalize their application to subtle problems.

The second half of the hypothesis is slightly less clear. From knowing their age alone, probably none of the subjects would be expected to pass the formal operations problems. Although scoring is less than perfectly reliable, the obtained data suggest that about half the boys above 10 years of age can deal with the problems given. This suggests some precocity in the attainment of formal operations by very bright boys while the initial hypothesis predicted none.

If the prediction of no precocity in formal operations proves to be false, as it apparently does, a quantitative formulation may be necessary. The most difficult concrete operations problems and the simpler formal operations problems would not be very different in value if they were scaled on age (i.e., most 12-year-olds fail conservation of volume, some pass the floating bodies problem). If the present study is approximately correct, however, the probability that a very bright child of six years will pass conservation of volume is high, and the probability that he would pass the floating bodies problem almost nil. This suggests that the relative precocity of bright children within a Piagetian stage is much greater than across stages and supports the belief in the psychological reality of Piagentian stage structures. Thus, the growth of intelligence may be compared to the skilled use of tools. The development of the tools themselves (operations) may be a human species specific trait relatively stable across a range of environments. How well the tools will be used is a function of a number of things including experience and innate capacity. Bright children use the tools characteristic of their developmental stage very well compared to their peers. On the other hand, if they develop new tools any sooner at all the differences are not nearly as striking.

Footnote

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