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Cognitive Capacity of Very Young Children

Abstract. *Children between 2 years, 6 months old and 3 years, 2 months old correctly discriminate the relative number of objects in two rows; between 3 years, 2 months and 4 years, 6 months they indicate a longer row with fewer objects to have "more"; after 4 years, 6 months they again discriminate correctly. The discriminative ability of the younger children shows that the logical capacity for cognitive operations exists earlier than previously acknowledged.*

J. Piaget has investigated the mistakes which children make in solving simple problems (1). In the most often quoted of Piaget's experiments, a child sees two identical arrays of material and is asked if he, in fact, thinks they are "the same." For example, a child of four characteristically replies that the two identical rows of four pellets in Fig. 1a are, in fact, "the same." The experimenter then adds or subtracts some material in one of the arrays and changes its shape at the same time. He again asks the child if both arrays have the same amount of material, or if one has "more." If the array is like the one in Fig. 1b, the same child reports incorrectly that there are now "more" in the upper row. However, a child of 5 correctly indicates that it is the array with the added material which has "more."

Various experimental techniques have been used to isolate the ages at which children develop the ability to ignore particular kinds of changes and to recognize when material is "conserved"

(that is, not perceived as modified in quantity), in spite of those apparent changes. The development of the different kinds of quantity conservations is interpreted by Piaget as a behavioral reflection of the development of general cognitive capacities. For example, the 4-year-old's failure to conserve quantity in the above pellet experiment indicates that he does not have the cognitive capacity to "reverse" situations; hence, he cannot transform Fig. 1b back to Fig. 1a and then recall which particular row had the two pellets added to it. He instead responds to the momentary "appearance" of the two rows in Fig. 1b and incorrectly reports that the longer row has "more."

All of the well-known experiments on the conservation of quantity have ignored children below the age of 4. The exclusion of younger children has appeared rational because 4-year-old children do not have quantity conservation. If a 4-year-old does not have conservation, why should we expect an even younger child to exhibit it? Although this argument was reasonable, it was also misleading. The present study of over 200 children shows that under 3 years 2 months (3-2), children exhibit a form of quantity conservation; they lose it as they get older and do not exhibit it again until they are about 4 years 6 months (4-6).

Seven age groups of children from 2-4 to 4-7 were tested in individual sessions with two experiments involving quantity judgments. Each experiment used two pairs of rows like those shown in Fig. 1, a and b. One of the experimental sequences for each child had clay pellets while the other had M & M candies (candy-coated chocolate pellets). In each experimental sequence the child was first presented with adjacent rows of four, as in 1a, and he was asked if they were the "same." The experimenter then modified the arrays into a situation like 1b, in which a short row of six is adjacent to a longer row of four. In the experiment with clay pellets he was then asked which row had "more." In the experiment with M & M's the responses to situation 1b were nonverbal: instead of asking the child to state a quantity judgment, the experimenter asked him to "take the row you want to eat, and eat all the M & M's in that row." The order in which the M & M experiment and clay experiment were presented was balanced for each age group, as was the orientation of the arrays on the

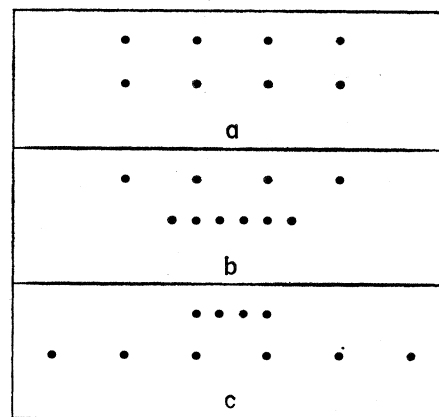


Fig. 1. The length of the rows in (a) was 7 inches (18 cm) for M & M's and 8 inches (20 cm) for clay pellets; in (b) 7 and 3 inches (18 and 8 cm) for M & M's and 8 and 5 inches (20 and 13 cm) for clay pellets. There was a 1½-inch (3-cm) space between each of the four clay pellets and a 2-inch (5-cm) space between each of the four M & M's. The clay pellets were ½ inch (1.3 cm) in diameter. The M & M candies were all of the same color.

table in front of the child (2). Each session took about 10 minutes. The experimenter wrote down the response of the subject, and a tape recording was taken for subsequent analysis.

The valid responses (3) are summarized by age in Fig. 2; the ordinate represents the proportion of success in choosing or naming the row which, in fact, had more (that is, the proportion of "conserving" responses) and the abscissa represents increasing age. Two bar graphs are presented, one for choosing which row of clay pellets had "more," (Fig. 2a) and one for taking a row of M & M's (Fig. 2b). Both experiments show a decrease in conserving responses by age, which is at a minimum in the group between 3-8 and 3-11. Thus, as the children get older than 2-6, they get worse, rather than better, at quantity conservation. Even more striking is the fact that the 23 youngest children (under 2-8) show extremely high numbers of conserving responses—100 percent of verbal responses on the quantity of clay pellets and 81 percent for taking rows of M & M's. The decrease with age is strongly significant for the verbal judgments ($P < .001$ by chi-square comparing 2-4 to 2-7 and 4-0 to 4-3 ages for verbal judgments) and non-significant for responses to M & M's. At 4-6, the children again show conservation for both kinds of quantity judgment (significance of increase in conservation of clay pellets between 4-0 to 4-3 and 4-4 to 4-7 = $P < .01$;

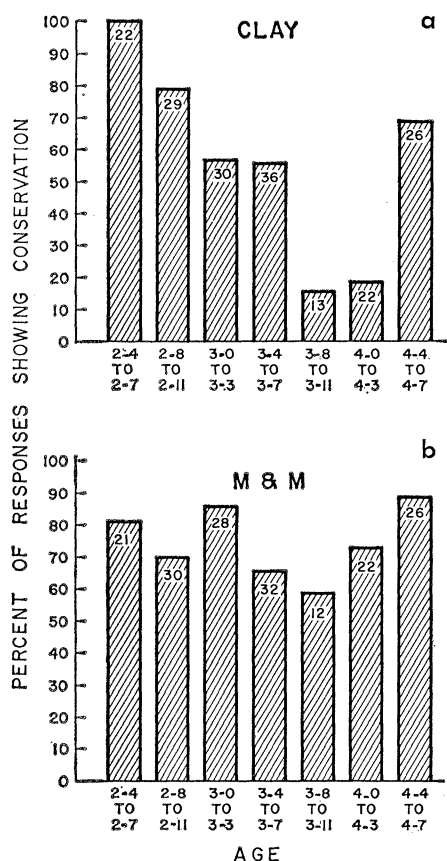


Fig. 2. The proportion by age of responses choosing the row with more members in the situation shown in Fig. 1b. Numbers inside bars indicate total number of subjects of that age.

for eating of M & M's, $P < .01$ by chi-square).

Occasionally children responded one way on verbal judgments of which clay row had "more," yet in the case of M & M's they took the other row to eat. This might show some uncertainty in the child's capacity to judge quantity. To strengthen our basic finding that children at 2-6 and 4-6 show more conservation than children of 4-2, we separated those children who showed consistent responses on both M & M's and clay pellets from children with inconsistent responses. Among the children who gave consistent verbal and nonverbal responses, there were more consistent nonconservation responses at age 4-2 than at 2-6 ($P < .02$ by chi-square) or at 4-6 ($P < .03$ by chi-square). Furthermore, if a child gave inconsistent responses, it is more likely that the single conserving response was to the M & M's than to the clay pellets ($P < .01$ by chi-square in favor of M & M conservation) (4).

Our results indicate that the inability to conserve quantity is a temporary phase in the developing child. The

child does not gradually acquire quantity conservation during his 4th year; rather, he reacquires it. The fact that the very young child successfully solves the conservation problem shows that he does have the capacities which depend on the logical structure of the cognitive operations. Eventually, he develops an *explicit* understanding of these operations: at age 5 he solves the same problem by counting the pellets in each row. We think that the temporary inability to solve the conservation problem reflects a period of overdependence on perceptual strategies. These strategies develop on the basis of experience with correlations of apparent shapes and actual quantity. Surely, it is a general rule that longer arrays usually have "more" components, and a reasonable perceptual expectancy would reflect this. Just after the young child incorporates this expectancy into his perceptual scheme, he is misled by the apparent length of a row into thinking that it has more components. The fact that children at all ages tend to take the M & M row with "more" indicates that this perceptual strategy can be overcome, given sufficient motivation to do so. Eventually, the child develops a more sophisticated integration of the logical operation with his perceptual strategies which allow him to count the individual members of an array. He then has the capacity to ignore his perceptual expectancies in those critical instances in which they are not confirmed. The intermediate age "nonconserving" child cannot disengage his perceptual strategies in this way. Thus, nonconservation behavior is a temporary exception to human cognition, not a basic characteristic of man's native endowment.

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References and Notes

1. J. Piaget, *The Child's Conception of Number* (Humanities, New York, 1952); *The Origins of Intelligence in Children* (International Univ. Press, New York, 1952).
2. Subjects were children attending local play groups and private nursery schools in the Greater Boston area as well as some participating in the Harvard Infant Study. Older and younger children were drawn from the same schools and groups whenever possible and were often siblings.
3. Occasionally a child would refuse to respond, or would choose the clay pellets or M & M candies one at a time instead of the whole row. These responses were ignored.

4. We also ascertained that the conservation responses in the young children are not due to a tendency to take and to name short rows. Sixteen children, age 2-4 to 2-9, were presented with an array in which the row with six clay pellets or M & M's is in fact longer (Fig. 1c). In this condition there were 22 conservation responses (picking or naming the long row) and ten nonconservation responses. Out of eight children who responded consistently on M & M's and clay judgments, seven showed consistent conservation responses. This indicates that the young children are attending to the actual quantity in a row. Preliminary analysis indicates that for children below 3 years of age, experimental order of M & M's and clay did not affect the tendency to exhibit conserving responses.
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Optical Differentiation of Amoebic Ectoplasm and Endoplasmic Flow

Baker and Johnston (1) offer photographic evidence that they have detected "optical activity" in living amoebas. The term "optical activity," which has traditionally meant optical rotation, is redefined by the authors to include "any polarized light phenomenon." However, their "dynamic polarized light detection system" is, in fact, incapable of differentiating among several phenomena detectable with polarized light (phase shifts due to birefringence, optical rotation, linear or circular dichroism, refraction absorption, surface depolarization, and light scattering). The photograph shown in Fig. 2 could have resulted from a mixture of any of these "optical activities."

In optical analysis one should identify the type of light-matter interaction observed in specimens and then proceed to quantify this interaction. Usually identification and quantification are accomplished simultaneously by null compensation for phase shifts or rotation of the plane of polarization (2). Another electronic detection technique using phase modulation referred to by the authors (3) does, in fact, use the null method through automatic compensation of rotation, phase shifts due to birefringence, and dichroism. The null compensation method, in any event, separates the phenomena detectable only in polarized light from absorption refraction and light scattering, properties that are not only detectable