cytized may have been initially deposited on the mucus lining of the trachea, bronchi, and bronchioles and cleared during the first day.

The percentage of pulmonary macrophages with engulfed particles increased to a maximum value during the first 2 hours. From 5 to 65 percent of the isolated pulmonary macrophages had phagocytized particles during the first 3 hours. The phagocytic indices of each group were essentially unchanged during the succeeding 25-day observation period, although considerable variation among individuals occurred. The phagocytic index rose with increasing amount of plutonium deposited in the lungs (Fig. 3), demonstrating that the number of particles phagocytized was somewhat dependent on the number of particles that were administered and deposited in the lungs.

These preliminary results showed that a large number of the plutonium particles deposited in lung, and subject to a slow clearance with a biological half-life of several hundred days (*1*, *3*), were phagocytized and retained within pulmonary macrophages during the 25-day observation period. Death of macrophages and rephagocytosis of particles may have occurred during this period. The technique of pulmonary washing appears to offer an experimental method for the quantitative study of the deposition and retention of inhaled particles as well as offering possibilities for therapeutic removal of toxic particles from the lungs of accidentally exposed individuals.

C. L. SANDERS
R. R. ADEE

Battelle Memorial Institute,
Pacific Northwest Laboratory,
Richland, Washington 99352

References and Notes

1. W. J. Bair and D. H. Willard, *Health Phys.* **9**, 253 (1963).
2. P. E. Morrow, F. R. Gibb, H. Davies, J. Mitola, D. Wood, N. Wraight, H. S. Campbell, *ibid.* **13**, 113 (1967).
3. W. J. Bair, D. H. Willard, J. P. Herring, L. A. George, *ibid.* **8**, 639 (1962).
4. P. E. Morrow and L. J. Casarett, in *Inhaled Particles and Vapours*, C. N. Davies, Ed. (Pergamon Press, Oxford, England, 1961), p. 167; R. G. Thomas, *Health Phys.* **14**, 111 (1968); L. J. Casarett and P. S. Milley, *ibid.* **10**, 1003 (1964).
5. C. L. Sanders, *Diagnosis and Treatment of Deposited Radionuclides* (Excerpta Medica Foundation, Amsterdam, in press).
6. C. L. Sanders, unpublished.
7. Alveolar macrophages, monocytes, large lymphocytes, and histiocytes were collectively termed pulmonary macrophages. Other nucleated cells found in lung washings, such as small lymphocytes and epithelial cells, did not phagocytize plutonium particles.
8. C. L. Sanders and R. R. Adee, unpublished data; R. R. Adee, C. L. Sanders, J. D. Berlin, *Health Phys.*, in press.
9. R. J. Ramirez, *Arch. Intern. Med.* **119**, 147 (1967); *New Engl. J. Med.* **274**, 469 (1966).
10. K. C. Richardson, I. Jarett, E. H. Finke, *Stain Technol.* **35**, 313 (1960).
11. We thank Dr. W. J. Bair for review of this paper. Technical help of V. T. Faubert and G. J. Powers is acknowledged. Work performed under AEC contract AT (45-1)-1830.

9 September 1968

Cognitive Capacities of Young Children: A Replication

Abstract. *Children between the ages of 3 years and 4 years 7 months correctly respond to the addition of objects in an array, to the numerical equality of arrays, and to their relative numbers. However, they are not able to conceptualize equality or inequality when objects are misaligned or spatially transformed. The Mehler and Bever assertion that very young children conserve the concept of number, with a decline and rise in performance, is not confirmed.*

Mehler and Bever (*1*) have reported that children below the age of 4 are capable of conserving concepts of quantity. This finding contradicts the reports of Piaget (*2*) and others who place these acquisitions at about age 6 to 7. This age difference in the acquisition of conservation is of theoretical consequence. Mehler and Bever's delineation of a decline in conservation performance from the very youngest age studied (2 years 4 months) and then a rise (with age) implies that these capacities are genetically determined and are a "basic characteristic of man's native endowment" (*1*). The Piaget position, on the other hand, is that these competencies reflect the influence of maturational and experiential determinants under the control of an internal self-regulating mechanism.

In contrast to the usual procedure of testing conservation with a relocation or transformation of objects first identified as equal with respect to a quantitative property, Mehler and Bever used a conservation-of-inequality task based on the inequality of two sets of objects. More importantly, they both added objects to their numerical arrays and relocated them in a single operation. Thus it is not possible to know whether a child's response was due to addition or relocation, or both. It was my prediction that a controlled study which separated these operations would show that the results were due solely to the child's ability to deal with "more" in the additive sense of "more of," or in the relational sense of "more than," rather than with the conservation concept of "more than in the face of a transformation." I now report results of an experiment designed to test the correctness of this prediction.

The concepts measured were as follows: (i) Conservation of equality based upon an initial response of "same" to equal numbers of M & M's (candy-coated chocolate pellets) set in two rows and in one-to-one correspondence (the "before" condition of Fig. 1), followed by a relocation of one row either by expansion or contraction, and a continued response of "same" to the numbers in the two rows (the "after" condition). (ii) Conservation of inequality in which the "before transformation" condition is one of inequality of both number and location; the "after" condition is still one of inequality, but the beginning and terminal points of the rows are in either one-to-one correspondence or in a different spatial location from the "before" condition. In earlier studies (*3*, *4*) a distinction was made between transformational and static conservation. In the latter case no transformation takes place in the stimulus. A conserving subject is required to judge two rows as numerically equal in spite of a lack of alignment between them. In my study both static and transformation-conservation tasks were included in the test. (iii) Relational concept ("more than"): two rows unequal in number and extension had to be judged as unequal in number. (iv) Equality: two rows, equal in both number and extension (that is, in one-to-one correspondence) had to be judged as equal in number. (v) Additive concepts ("more of" or "less of"): one or two rows were presented and M & M's were added to or subtracted from a row.

In each trial a Mommy or Daddy doll accompanied each row. Responses represented a choice between the "same" or "different" and "more" or "same" amounts to eat. Two groups of children were tested in private nursery schools. One group was given the transformation tasks and the other the static tasks. Both groups were administered the same additivity tasks.

The data in Table 1 show different levels of performance. The level of conservation performance for conditions

Table 1. Response to conservation, relational, and additive tasks; average percent correct for trials in a series. Transformation and static tasks were administered to two different sample groups. Transformation groups numbered: (1) 7; (2) 16; (3) 21; (4) 16; (5) 15. Static samples numbered: (1) 6; (2) 16; (3) 23; (4) 17; (5) 15. Additivity tasks were the same for both samples; these data are reported for the combined numbers of both groups. Group 1 includes children from 3 years through 3 years 3 months; group 2, 3 years 4 months through 3 years 7 months; group 3, 3 years 8 months through 3 years 11 months; group 4, 4 years through 4 years 3 months; group 5, 4 years 4 months through 4 years 7 months. Figures in brackets represent correct response to the quantity of the array ("same" or "different") prior to the addition, and the quantity after the addition or subtraction. The figures in this category without brackets are for the correct response to the addition or subtraction operation alone. The arrangements (A–H) are shown in Fig. 1.

Trials	Group				
	1	2	3	4	5
A	14	15	19	15	9
B	33	44	41	35	30
C	24	33	30	29	38
D	33	47	37	47	47
E	17	63	52	59	67
F	67	81	65	88	87
G	47	65	67	77	82
	[18]	[40]	[42]	[61]	[68]
H	65	73	78	83	91
	[26]	[46]	[51]	[61]	[74]

of both equality and inequality is very low for all age groups as represented by the average percentage of correct responses in these trials. Since the probability of chance success by guessing in any static conservation trial is 50 percent and in any transformation trial is 25 percent, response is close to or below chance in all conservation conditions. Not a single child at any age tested was correct in all three conservation-of-equality trials, and only 7 percent in the oldest age group were correct in conservation-of-inequality trials. With a criterion of two out of three correct, the level of correct performance increases, but to no higher than 20 percent in any age group; there is no age trend.

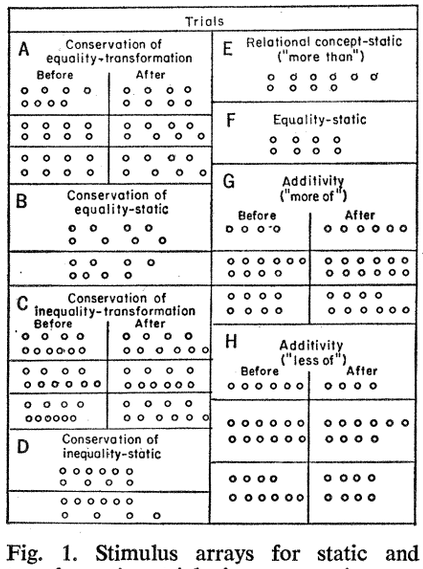

Fig. 1. Stimulus arrays for static and transformation trials in conservation, relational, and additive conditions.

By contrast, even the youngest children in the sample exhibit a high level of correct performance in the "equality" test, where number and extension of static arrays are equal. This is likewise true where the relational judgment ("more than") is made (*5*).

Although correct responses with respect to conservation of equality and inequality are greater in the static than in the transformation condition, both are at about chance level. This differs from data reported previously (*4, 6*) for equality-of-area judgments in children from kindergarten through fourth grade. Static conservation was consistently more difficult for those children to achieve than transformational conservation. This difference in performance suggests that younger children are unable to correctly utilize the information imparted by the transformation; that is, transformation leads to the incorrect "perceptual" inference that the longer or shorter row is different in number from the standard when it is in fact equal. Older children are more able to use the transformation information because of the possession of an inference-generating mechanism. Younger children apparently lack such a mechanism or, if they have it, are unable to use it; thus performance in both static and transformation conditions is determined by chance factors.

The additivity concepts ("more of" and "less of") are the only ones in the present instance which show an age trend (positive). An appreciable percentage of even the youngest age group respond correctly (*7*).

Young children, then, within the age range of 3 years to 4 years 7 months display very little, if any, conservation ability. They do have some conceptual capacities ultimately necessary for conservation, but they lack the inference-generating mechanism that makes possible a judgment of equality or inequality in the face of spatial transformation or dislocation. The high level of response of Mehler and Bever's subjects is most likely due to the combination of addition and relocation tasks in the experimental operations. The decline and rise in performance also reported by Mehler and Bever is not confirmed.

HARRY BEILIN
City University of New York,
33 West 42 Street,
New York 10036

References and Notes

1. J. Mehler and T. G. Bever, *Science* **158**, 141 (1967).
2. J. Piaget, *The Child's Conception of Number* (Routledge and Kegan Paul, London, 1952).
3. H. Beilin, *J. Exp. Child Psychol.* **1**, 208 (1964).
4. ———, *ibid.* **3**, 267 (1966).
5. This result is something of an anomaly since previously I found that in area judgments equality is more difficult to judge than inequality. The difference between the past and present results may be either a function of age (since the present subjects are younger than the kindergarten children of the prior study) or of the different quantitative concepts employed (that is, area as opposed to number) in that the defining characteristics of "same number" are better known to young children than the defining properties of "same area."
6. H. Beilin, in *Studies in Cognitive Development: Essays in Honor of Jean Piaget*, D. Elkind and J. H. Flavell, Eds. (Oxford Univ. Press, New York, in press).
7. The number of responses is somewhat less when the additivity response is contingent upon a correct prior response.
8. Supported in part by PHS research grant HD 00925-07 from the National Institute of Child Health and Human Development. I thank George E. Spontak and Sandra J. Dalton for assistance.

4 March 1968

What Children Do in Spite of What They Know

Abstract. *New studies support the hypothesis that young children have basic cognitive capacities but utilize them inefficiently; older children aid these capacities with generally valid cognitive heuristics which produce poor performance on critical problems.*

In a previous study of cognitive development we found that children of 2 years 6 months can successfully recognize a numerical equality and its transformation into an inequality whereas older children temporarily lose this capacity. We interpreted our results as demonstrating that the capacity to conserve relations between stimuli in the face of transformations is present in the 2-year-old; the older child loses this capacity temporarily due to