Reversibility in nonconservation of weight¹

FRANK B. MURRAY and PAUL E. JOHNSON, *University of Minnesota, Minneapolis, Minn. 55455*

Contrary to Piaget's position (Piaget, 1960, 1967, 1968), we argue that reversibility is both logically and psychologically irrelevant to conservation, because logically, simply inverting the conservation transformation provides no information about the property being conserved, and psychologically, because nonconservers give evidence of reversibility. Specifically, the data indicate that nonconservers think that an increase in a clay ball's temperature reduces its weight, and a decrease in its temperature increases weight.

The pivotal concept in Piaget's account of the intelligent behavior of young children is that of the "operation," which by his definition is a covert act that is reversible and part of a system of such acts (Piaget, 1960). "The criterion for the appearance of such operational systems is the construction of invariants or concepts of conservation" and conversely, "...when the most elementary forms of conservation are absent, it is a consequence of the absence of operational reversibility [pp. 8, 12]." This somewhat circular relationship of conservation and reversibility is the subject of this paper.

Other than conservation, the behavioral criteria for reversibility are difficult to specify. Piaget describes reversibility metaphorically as the child's mental capacity to undo, nullify, cancel, or invert a mental operation. When a child understands an operation, Piaget insists that "he also understands, by this very fact, the possibility of its inverse [Tanner & Inhelder, 1960, p. 80]." That is, if the S understands, or acts as if he understands, an operation leading from A to B, he understands the inverse operation B to A. If S possesses the additive operation he possesses as well the subtractive form of the same operation.

It is argued that in the conservation problem when a round clay ball is flattened into a pancake, the nonconserving child is mentally unable to undo the operation or transformation, and consequently he is unable, as well, to understand that the ball and the pancake have the same amount of clay, weigh the same, or take up the same amount of space. The conserving child, on the other hand, is able to undo the transformation mentally, and in fact he

often supports his correct judgment with the explanation that the pancake could be rolled into the original ball, and because of that nothing has really changed.

The argument of this paper, in part, is that on purely logical grounds the reversibility of the transformation is irrelevant to the conservation judgment since it provides no evidence that the property of the object in question did not, in fact, change while it was in the transformed state. That an ice cube or a clay pancake can be returned to its original state as a quantity of water or as a clay ball is no guarantee at all that its volume, etc., as an ice cube or pancake was the same as its volume, etc., as a quantity of water or as a clay ball. Because a stretched rubber band can be returned to its original shorter length clearly does not mean that it was not longer when it was stretched. When the child offers a reversibility reason to justify a conservation response, his argument is irrelevant and, strictly speaking, incorrect.

In fact, knowing that a transformation can be empirically or even logically undone should be of no real help in the solution of the conservation problem, since that solution in some sense depends upon a consideration of the relevant and irrelevant transformations of the concept in question (Johnson & Murray²; Murray & Johnson, 1968). One might, in this regard, expect that the nonconservers, if his nonconservation has any validity at all, would show reversibility and consistency in his error. If the nonconservers really thinks that flattening a pancake decreases its weight, he might very well think that rolling back into a ball increases its weight; that is, this particular shape transformation changes an object's weight for him just as an addition or subtraction transformation changes an object's weight for most adults.

The particular transformation investigated in the data reported here to support the speculations above was an imagined temperature transformation and its effect on second graders' conservation of weight.

SUBJECTS

From four schools in Minneapolis and St. Paul that had been using the MINNEMAST curriculum unit on weight, 120 second-grade Ss were randomly selected. The mean age of the sample was 8:1.5 years, all Ss were white. The sample was randomly assigned to four groups with the restriction that there be 15 boys and 15 girls in each group.

MATERIALS

The materials for the conservation problems reported in this paper were: one blue clay ball (4.5 cm in diam), one green clay ball (7.5 cm in diam), and a beam balance.

PROCEDURE

All Ss were tested individually in a small office at each school, and each S was presented with 18 conservation-of-weight problems in a different random order. Only 6 of those problems will be discussed here since only these are relevant for the topic of this paper. Ss were randomly assigned to four groups which differed in these ways: Groups 1 and 3 received the problems in the forward form, i.e., the transformation of a clay ball from A to B; Groups 2 and 4 received the problems in reversed form, B to A; Groups 3 and 4 had a beam balance present to refer to, and Groups 1 and 2 had no beam balance.

Subjects in all groups were shown two wooden blocks, one larger than the other, and were told, "These are two building blocks; would you hold one in each hand. I'd like to know what you think about how much they weigh. Can you tell me, is this one heavier than this one, or is this one heavier than this one, or do they both weigh the same?" (E pointed to the block in question each time it was mentioned). All children in the sample correctly answered the question.

In addition, the balance groups (3 and 4) were asked, "How would you use this balance to find out which was heavier?" All children in these groups used the balance appropriately.

Before the conservation problems were presented, Ss were shown a ball of clay and asked, "Do you know what this is?" and were permitted to manipulate it before they were told, "Today we're going to play with this clay in different ways, and I'm going to

Table 1
Number of Ss in Each Group (1, 2, 3, 4) Responding Same, More, Less to Each Problem. (N = 120)

Problem Number	Group 1			Group 2			Group 3			Group 4		
	Same	More	Less	Same	More	Less	Same	More	Less	Same	More	Less
1	0	29	1	4	0	26	1	29	0	1	0	29
2	1	29	0	1	0	29	2	28	0	1	0	29
3	10	18	2	17	3	10	9	20	1	7	4	19
4	9	19	2	15	4	11	11	17	2	7	3	20
5	9	3	18	18	8	4	12	1	17	11	18	1
6	11	3	16	17	10	3	14	1	15	9	14	7

Table 2
Number of Nonconserving Ss (More, Less) in Each Group Who Shifted and Were Consistent Between Problems 3 and 5 and Problems 4 and 6

		Group 1		Problem 3		Group 3		Group 4	
		More	Less ¹	More	Less ⁴	More	Less ¹	More	Less ³
Problem 5	More	1	1	0	5	0	1	2	15
	Less	16	1	1	2	14	0	1	0
Problem 6	More	3	0	2	5	0	1	3	7
	Less	13	2	1	1	11	0	0	7

Binomial test: ¹ $p = .001$, ² $p = .003$, ³ $p = .008$, ⁴ $p = .109$

ask you what you think about it." Ss in Group 1 were presented with the following six problems and asked the following questions:

(1) The child was told to watch as E added a piece of blue clay to the blue ball, and asked, "Do you think the clay ball weighs more now than it did before, or does it weigh less now than before, or does it weigh the same now as it did before?"

(2) Problem 1 was repeated with the green ball.

(3) Subjects were shown the blue ball, and were directed, "Imagine that we left this clay outside in the winter, and when we came back it was hard and cold. Do you think it would weigh more when it was hard and cold that it does now, or do you think it would weigh less, etc., or do you think it would weigh the same, etc.?"

(4) Problem 3 was repeated with the green clay ball.

(5) Subjects were shown the blue clay ball, and were directed, "Imagine that we left this clay outside in the summer and when we came back it was hot and very soft. Do you think it would weigh more when it was hot and soft than it does now, or do you think it would weigh less, etc., or do you think it would weigh the same, etc.?"

(6) Problem 5 was repeated with the green ball.

Essentially the same problems were presented to the Ss in Group 2 (reversed form) except that in Problems 1 and 2 a piece of clay was removed from the ball; in Problems 3 and 4 Ss were told that a cold ball was brought inside where it was warm, and the question was, "Do you think it weighs more inside than it did outside, etc.," and in Problems 5 and 6 Ss were told that the ball that had been left out in the heat was brought inside where it was cooler, and were asked, "Do you think the ball weighs more inside than it did outside where it was hot, etc.?"

Group 3 was presented the forward and Group 4 the reversed problems with the addition that the expression, "would weigh more (less or same)," in each question was preceded by the expression, "if we weighed it on the balance would it . . ."

RESULTS

The number of Ss in each group who responded that the clay ball weighed more than, less than, or the same as, the same clay ball after each problem's transformation is presented in Table 1. Those Ss on Problems 3, 4, 5, and 6 who said that the ball weighed the same are conservers, by definition, and those who said the ball weighed more or less are nonconservers for the same reason. The data from Problems 1 and 2 indicate clearly that nearly all Ss, conservers and nonconservers, were aware that added clay increased weight, and that subtracted clay decreased the weight of the ball in question.

The differences in the proportions of more and less responses among the nonconserving Ss were found to be significant (chi square, $p < .001$) between the forward and reversed forms of the transformations of Problems 3, 4, 5, and 6 for the balance groups (3 and 4) and nonbalance groups (1 and 2; $p < .01$ for Problems 5 and 6). Nonconserving Ss thought that increasing a clay ball's temperature (moving it from cold to warm) reduced its weight, and consistently that decreasing its temperature (moving it from warm to cold) increased its weight.

Within each group, Problems 3 and 5 and Problems 4 and 6 required the same Ss to judge the effects of increasing and decreasing temperature on the same clay ball. In all but Group 2, where the data are clearly in the expected direction, significant numbers (binomial test, $p < .01$) of the same Ss who judged that decreasing temperature increased weight judged, on the other hand, that increasing temperature reduced weight (Table 2).

There was high reliability between the blue and green clay ball forms of each problem in that the following number of Ss out of 30 gave the same response between Problems 1 and 2, 3 and 4, and 5 and 6: Group 1, 28, 25, 25, respectively; Group 2, 27, 26, 25, respectively; Group 3, 29, 27, 28, respectively; and Group 4, 28, 24, 21, respectively.

DISCUSSION

The nonconserving child is apparently quite "logical" and consistent in his error. In

fact, the principle source of his error seems not to be an unawareness of the inverse of the transformation, but a misjudgment of the relevancy of the transformation he is asked to evaluate. In other words, it would seem that conservation is much more a subject matter variable than it is a logical or inferential variable.

Bruner and his colleagues (1966) have argued, for different reasons than those presented here, that reversibility is not at the heart of the conservation problem. Piaget (1967, 1968) has responded that Bruner has confused reversibility with "renversabilité," or empirical reversibility, which, he argues, is a physical concept, such as the awareness that a spring or elastic can return to its original state. In empirical reversibility, the return may be incomplete (i.e., the spring never returns exactly to its former state), or the transformation from A to B may be different sufficiently from the transformation from B to A (or A' in the case of incomplete physical return) to be considered a separate operation. In the present study, we would argue that cooling and warming are as much the same operation as are addition and subtraction (the most often cited example of reversibility), and that the transformations examined in the present investigation were not empirical and physically performed, but were imagined and abstracted transformations that were uncontaminated by the physical constraints of the empirical situation. There is also little doubt that the nonconservers of this study possessed the addition-subtraction operation or schema. In any event, the burden is upon the Genevans to provide the behavioral criteria that distinguish reversibility from "renversabilité," and to specify more clearly the kind of "careful experimentation . . . necessary to distinguish the two concepts [Piaget, 1967, p. 533]."

It may very well be that reversibility is a property solely of the logical model that Piaget has constructed to describe intellectual development, and, like the formal grammar of language, it need not have a reference in the behavior it best describes. In that event, it is not a category of behavior, and as such it requires no explanation in psychology.

REFERENCES

- BRUNER, J. et al. *Studies in cognitive growth*. New York: Wiley, 1966.
- MURRAY, F., & JOHNSON, P. A model for relevant and irrelevant transformations in children's concept of weight. In H. Hausdorf (Ed.), *A.E.R.A. Paper Abstracts, 1968 Annual Meeting*. P. 308.
- PIAGET, J. *Logic and psychology*. New York: Basic Books, 1960.
- PIAGET, J. Review of Bruner et al, *Studies in cognitive growth*. *Contemporary Psychology*, 1967, 12, 532-533.

PIAGET, J. *On the concept of memory and identity*. Barre, Mass.: Clark University Press, 1968.

TANNER, J., & INHELDER, B. (Eds.), *Discussions on child development*. Vol. 4. New York: International Universities Press, 1960.

NOTES

1. This work was supported in part by a grant to the MINNEMAST Center at the University of

Minnesota from the National Science Foundation (GE-3), and in part by grants to the University of Minnesota Center for Research in Human Learning from the National Science Foundation (GS-1761), the National Institute of Child Health and Human Development (HD-01136-04), and from the Graduate School of the University of Minnesota.

2. Johnson, P., & Murray, F. A framework for the analysis of the child's concept of weight. Submitted for publication, 1969.

The effects of stimulus hue on backward masking under conditions of monoptic and dichoptic stimulus presentation¹

LEON W. TEFT, *University of Bridgeport, Bridgeport, Conn. 06602*

Stimulus hue is a significant variable in visual backward masking when target and mask figure-ground brightness contrast is eliminated. Target stimulus hues are ordered from blue, red, green, to yellow in terms of their resistance to masking by hue. A similar ordering was found for masking stimulus hues in terms of their average inhibiting effect on all target stimuli. Significantly more masking occurred under dichoptic conditions of stimulus presentation.

In general, backward masking refers to the inhibition of the perception of a test stimulus when this stimulus is followed in close temporal succession and spatial proximity by a masking stimulus. Many investigators have explored backward masking in the visual modality and have attempted to define the parameters of this phenomenon. Excellent reviews of masking research have been provided by Raab (1963) and Alpern (1952). Taking as their measure of backward masking the difference in test stimulus detection thresholds under conditions of the presence and absence of a masking stimulus, investigators have found masking effects to be a function of the type of stimulus employed (Schiller, 1965), i.e., light flash or pattern; stimulus intensity (Kolers, 1962); duration of interstimulus interval (Eriksen & Hoffman, 1963), and mask (Alpern, 1953); spatial proximity of test and mask stimulus contours (Werner, 1935); and method of stimulus presentation (Schiller & Wiener, 1963), i.e., monoptic (both stimuli to the same eye) and dichoptic (the two stimuli to different eyes). This list of parameters, while not exhaustive, represents the major focus of research in this area.

The aim of the present experiment was to

explore the effects of another stimulus dimension, viz hue, in the backward masking paradigm. Baroncz observed chromatic masking with colored flashes of light; however, the effect was found to be highly dependent upon the utilization of a narrow range of interstimulus intervals (Alpern, 1952). Werner (1935) in his classic study of contour formation reported chromatic masking with selected colors and backgrounds. The findings of these two experiments point to hue as a significant variable in backward masking; however, it is to be noted that in both experiments the effect of hue was confounded with brightness contrast between figure and background. Another deficiency of these experiments was the failure of the investigators to report in quantitative terms the stimulus specifications. The present experiment was designed to overcome these deficiencies by systematically varying target and mask hue relations in a quantitative paradigm. In addition, the experimental design employed monoptic and dichoptic stimulus presentation to yield data on the relative contributions of central and peripheral mechanisms to the masking effect.

METHOD

Stimuli were presented in a specially designed seven-field tachistoscope driven by a Scientific Prototype Modified Model 1B three-channel timer. The use of a split-field balanced optical system permitted the monoptic or dichoptic exposure of stimuli. Identity of hue and brightness in the six stimulus fields (excluding the fixation field) was accomplished by including in all stimulus fields an equal number of reflection and transmission Inconel coated 30%-30% mirrors. The light source for each field consisted of two cold cathode mercury vapor argon lamps coated with magnesium and tungstate phosphor. The maximum rise

and fall of the lamps was rated at 2.5 msec. The target stimuli were four sets of 18 letters of the alphabet (E, F, G, I, N, O, R, and V were omitted). The letters were $\frac{3}{4}$ -in. block cut from Munsell notations 5R 5/4, 5G 5/4, 5Y 5/4, and 5B 5/4. Each of the letters was centered on a $2\frac{1}{4}$ -in. square gray N 5/ background. This background was used to eliminate brightness contrast between figure and background. The four masking stimuli consisted of a $1\frac{1}{8}$ -in. square lattice pattern cut from the four Munsell hues. The masking stimuli were mounted on a $2\frac{1}{4}$ -in. square N 5/ background. Ss looking through the viewing eyepiece saw a 5×8 -in. homogeneous white fixation field at a brightness of 1.1 ft-L. Ss were instructed to center their gaze on the central portion of the fixation field. The stimulus fields were masked down to a $2\frac{1}{4}$ -in. square and subtended a visual angle of 2.5 deg. The target and masking figures subtended visual angles of .9 and 1.3 deg, respectively. All target and mask fields were equated for brightness at 1.5 ft-L.

Six paid Ss with normal color and acuity vision served in this experiment. Pilot research was conducted in which identification thresholds were obtained for all Ss for all letters of the four hues with left and right eyes. Nonparametric analyses of the data revealed no significant differences attributable to letters or viewing eyes. Significant differences were obtained for hues and Ss. Further pilot work indicated that 40%-60% masking occurred when the target stimulus, followed after a 35-msec dark interstimulus interval by a 200-msec mask, was presented for a duration of 20 msec above threshold. Accordingly, the target stimuli durations were set at 20 msec above each S's threshold for identification of letters of each of the four hues. The unilluminated interstimulus interval was set at a constant 35 msec. The temporal duration of the mask was fixed at 200 msec. Each trial, then, consisted of the following: (1) fixation field, (2) verbal ready signal, (3) presentation of target, (4) interstimulus interval, (5) mask, (6) reappearance of fixation field, and (7) S's response, i.e., identification of letter if perceived. There were 18 trials for each of the conditions comprising a total of 1152 measures for each of the Ss.

RESULTS AND DISCUSSION

The data (number of correct identifications for each condition) were treated in an analysis of variance. The results of this analysis showed a significant difference in masking for the monoptic and dichoptic viewing conditions ($F = 10.23$, $df = 1/6$, $p < .05$). The mean number of correctly identified letters of all hues with monoptic presentation of target and mask was 9.23. For dichoptic presentations the