Conservation of weight in infants*

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Abstract

Conservation of weight can be defined as the ability to affirm that the weight of an object remains invariant during the transformations of the form of the object. It is known to be achieved at a conceptual level at about 9 years of age. The behavior of infants seems to indicate that between 6 and 18 months of age they develop a sensorimotor form of conservation.

1. Introduction

Piaget (1937, 1941a, 1967) has described the development of the concept of conservation in children between 4 and 14 years of age. At the beginning of this period children are incapable of affirming that the volume, weight or substance of an object is independent of its arrangement in space. If such a child is shown two identical balls of plasticine, he will agree that there is the same amount in each and that they weigh the same. If one ball is then rolled out into a sausage shape, with the child watching the transformation, the child will typically say that there is more plasticine in the sausage than in the remaining ball and that the sausage will weigh more than the ball because it is longer or that there is less plasticine and the sausage will weigh less because it is thinner. The child does not realize that weight, volume and substance are invariant under transformation of shape. At the end of this stage of development, children are aware of this invariance during transformations. These acquisitions originate in the sensorimotor behavior of the baby. The baby elaborates through his actions what the child between 4 and 10 years elaborates by means of his thought processes (Piaget, 1937, 1941a, 1967). Consequently, it is important to study the way in which this construction is effected at these more fundamental levels (Mounoud, 1971, 1973).

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Conservation or the lack of it must have effects on the success or failure of simple, everyday behavior. Consider the act of picking up an object and transporting it to the mouth, an act that children engage in from the age of six months or so. For that act to be performed successfully, the child must adjust the force of his grip to the weight of the object – if the grip is too light, the object will slip out of the hand; if too strong, the object may be crushed. In order for the baby to transport various different objects to his mouth with accuracy, he must appropriately adjust the tension of his arm muscles to the weight of the objects. He must relate the variations in size and form with variations in weight and also must recognize that transformations of observable aspects of the object or of the distribution of its elements do not entail a modification of its weight. Most children in most cultures play with plastic substances – playdoh, plasticine, flour and water or plain clay – whose shape changes in the course of the play, leaving weight, volume and substance unchanged; every time this happens the child is faced by a conservation problem at a behavioral level. While conservation of weight at the concrete operational stage is evidenced at 8 or 9 years, casual observation would indicate an awareness of conservation in behavior well before that age. The experiments to be reported here were designed to make such observations in a systematic way. The results indicate that conservation, realized through actions, is achieved during infancy by the age of 18 months.

Conservation of weight was selected for study. As was mentioned above, accurate transport of an object requires at least two adjustments to the weight of the object, the degree of muscular contraction of the arm and the force of the grasp. Before testing for conservation of weight it is necessary to ensure that the relevant behaviors have certain other characteristics. First of all the subject must show a differentiated response to weight; if a subject simply applies the same pressure or arm tension every time any object is presented, giving the same response on every occasion regardless of weight, there is no point in testing for conservation since conservation behavior would necessarily appear. Suitable response differentiation can be demonstrated by adaptive changes in response to a single object. The first time anyone, even an adult, is presented with an unfamiliar object which is not part of a set, there is no basis on which to judge the weight of the object. The weight might be overestimated or underestimated, but only by purest fluke could even an adult correctly gauge the weight of such an object. On repeated presentations, however, force of grasp and arm tension should adjust to the weight of the object. To be relevant to conservation, such adjustments must be anticipatory and based on visual information. Thus the improvement in performance must be specific to objects which can be identified as the same on the basis of visual information, so that anticipation of weight is made prior to actual manipulation of the object.

However, adapted responses to a single familiar object do not demonstrate sufficient capacity to make conservation testing worthwhile. Before beginning conservation testing it is necessary to establish that the adaptation is based on visual *size*. An infant could adapt to a single object, demonstrating perfect behavior, by recognizing the object on the basis of pattern or markings on it. If the relevant pattern or mark were invariant under the shape transformation, then we would necessarily obtain conservation behavior with no need for attainment of the concept that weight is invariant under shape transformations. Only if the visual basis for adapted behavior is seen size is conservation testing meaningful. One can only demonstrate that seen size is the basis of adaptation to the weight of a single object if there is some transfer of adaptation to a new object of the same material but different size. If the baby adapts to an object of size x and weight y, one could then give him an object of size $2x$ and weight $2y$. Ideally there would be no error at all on first presentation of $2x$, if seen size were the basis of the adaptation. An acceptable criterion of performance would be that the error on first presentation of $2x$ be no greater than the error on the last presentation of x. A minimal criterion would be that the error with $2x$ for a group given experience with x would be that they showed an error indicating greater expectation of weight than a group given no previous experience of x. In the context of behavior this could mean a lessened drop of the arm on taking $2x$.

If these criteria are met one can proceed to test for conservation behavior. A paradigm for test would be to adapt the subject to a particular object and then to transform the object. If there is conservation of weight, the first response after transformation should ideally show no errors, or no greater error than the last response prior to transformation.

To summarize then, it is necessary before testing for conservation to ensure that the subject is capable of differentiated adaptive responses to weight, which are anticipatory and based on seen size. If these criteria are met one can proceed to conservation testing.

In the context of the two adjustments necessary for accurate transport of an object, error as used above means a drop or elevation of the arm on taking an object or else application of too little grasp force to hold an object or more force than is required to hold the object.

2. Experiment 1

2.1 *Subjects*

Six groups of five infants aged between 6 and 16 months served as subjects in this experiment.

2.2 *Procedure*

The objects used in the arm tension experiment were a series of brass rods, all 2.5 cm in diameter, of length 2.5 cm, 5.0 cm, 7.5 cm and 10.0 cm, whose weights were 110 grams, 220 grams, 330 grams and 440 grams, respectively. They constituted the seriation set. The third cylinder in this series (330 gr.) was paired with a visually identical hollow cylinder weighing 100 gr. There was also an object which could be transformed, a

15.0 cm high 2.5 cm diameter brass rod, weighing 550 grams, hinged in the center so that it could be doubled over and locked to make a double rod 7.5 cm high. An additional transformable object that was occasionally used consisted of a lump of playdoh that had lead bearings concealed in it. This object could be rolled into a ball or a sausage without revealing the lead. Its weight was 250 grams, its volume 50 ccs.

Subjects were initially given the seriation set in ascending and then descending order (item 1). Each object was presented several times in a row, followed by the next in the series, again presented several times in a row. Objects were presented by hand in such a way that the infants were forced to reach out to take them. The arm could thus drop, raise or rest stable. The item involving the illusory identity between the two cylinders (item 2), consisted of presenting three times in succession the heavy cylinder (item 2a) and immediately after presenting the hollow cylinder (item 2b). (Response to this sequence tells us whether or not the infant expects visually identical objects to weigh the same.) After this substitution item has been presented, the transformable object was introduced, either fully extended or doubled (item 3). After three presentations it was transformed with the infants watching and then presented again. This terminated the experiment, save for a few infants who were given a conservation test with the playdoh object. Behavior was recorded on videotape. The measure adopted was the amplitude of hand drop or hand elevation on presentation of an object, measured by comparing the position of the hand on taking the object with its position 250 msecs later. The time interval was chosen to ensure that we were obtaining a measure of anticipation, our assumption being that 250 msecs was too short a time to allow for recovery from an initial error.

Response to item 1 was intended to tell us whether the baby was capable of adapted, differentiated responses to weight. Items 2a and 2b were intended to tell us whether or not these responses were cued by visual size, while item 3 was the conservation test.

2.3 *Results*

The arm drop measure worked well, except for infants of 11–13 months (see Figs. 1, 2 and 3). We would expect that if the infants were able to adjust their reaching and grasping behavior for the same object when it is given several times in succession, there would be a diminution in the amount of arm drop or arm elevation between the first and last presentations of the same object. Table 1 gives the results for item 2a. They indicate that at all the ages there was such an adjustment.[1]

1. Rather than taking the object and then transporting it, as the younger and older babies do, infants in the age range 11–13 months integrated taking and transport into a single movement. This made it impossible to use the simple arm-drop measure. A measure based on path and speed of movement would be required, and it would be difficult to give a simple quantitative measure of the aberrant trajectories produced. It is not therefore possible to include the data from this age group in Table 1.

Table 1.

Age	Mean drop (−) or elevation (+) on first presentation of object (item 2a)	Mean drop (−) or elevation (+) on third presentation of object (item 2a)	t*	p
6 months	−50	−20	5.0	<.005
7 months	−35	−10	6.25	<.005
8 months	−10	0	4.0	<.01
9.5 months	−20	+15	9.84	<.001
15 months	−30	−15	4.75	<.005

* $df = 4$

The next question asked concerned the basis for adjustment. If the babies were using the visual appearance of the object as a basis for inferring its weight and thereby utilizing a rule that the same object weighs the same each time it is presented, we would expect that presentation of item 2b, visually identical to but lighter than 2a, would result in an effective elevation of the arm when compared to the elevation or drop occurring on the third presentation of item 2a. Table 2 gives the results of the comparison of response to these two objects. As can be seen, it was only by the age of 9.5 months that the *appearance* of the object became critical in determining response to it. Only at that age did presentation of item 2b result in significant elevation of the arm. The seemingly successful adjustments of the younger infants were therefore not based on the use of visual indices. It is possible that they were based on a very subtle use of proprioceptive ones. However since these could hardly produce anticipation and the time interval between measures was too short for recovery from an initial error, it seems that there must have been some other basis for the adjustment. Inspection of their behavior indicated that these babies tended over trials to lock their arm against their body, holding the forearm tightly against the body, so that the weight of their body was acting as a counterweight to the weight of the object placed in their hand thereby cutting the possible range of elevation or drop. Thus on the criteria we have adopted, it is not possible to say whether or not these infants were showing visually based prediction of weight. However we can say that from 9.5 months on there is visually based prediction of weight for single objects, that infants above 9.5 months know that the visually same object weighs the same each time it is presented.

We must turn to the seriation data to discover whether visually based prediction of weight goes beyond prediction of the weight of a single familiar object and can be based on familiarity only with the material from which an object is made, with size used as an indicator of weight, regardless of familiarity with the specific size presented. If size can be so used, we would expect the first presentation of the later objects in the seriation set to elicit lesser arm elevations or drops than first presentation of the initial object in the series. The possible criteria for size determination were set out in the introduction. Sample data, Table 3, indicates that the 9.5-month-old group did not meet the two stronger criteria. Unfortunately the procedure used made it impossible to use the weakest criterion. The 15-month-old group by contrast met the second strongest criterion proposed, zero decline in accuracy. This group also showed zero decline in precision after transformation in the conservation test.[2]

Table 2.

Age	Mean drop (–) or elevation (+) on third presentation of item 2a	Mean drop (–) or elevation (+) on first presentation of item 2b
6 months	–20	–20*
7 months	–10	–10*
8 months	0	0*
9.5 months	+15	+40**
15 months	–15	+20***

* = NS
** $t = 3.01, df = 4, p < .05$
*** $t = 7.0, df = 4, p < .005$

Table 3. *Difference between movement on last presentation of second object and first presentation of third object in seriation task*

Age	Difference
6 months	6
7 months	–16
8 months	8
9.5 months	20
15 months	0

2. There are difficulties in a straightforward interpretation of such zero differences and in testing their representativeness of true mean values. We will return to this point in the results section of Experiment 2.

Figure 1. *Each frame shows two arm positions. 1) The position on taking the object and 2) the position of the arm at the end of its first excursion. At top is the reaction to the first presentation of an object; center – reaction to third presentation of that object. Note diminished arm excursion. Bottom – reaction to the visually identical but lighter object (item 2b). Note the extreme elevation shown in the bottom frame*

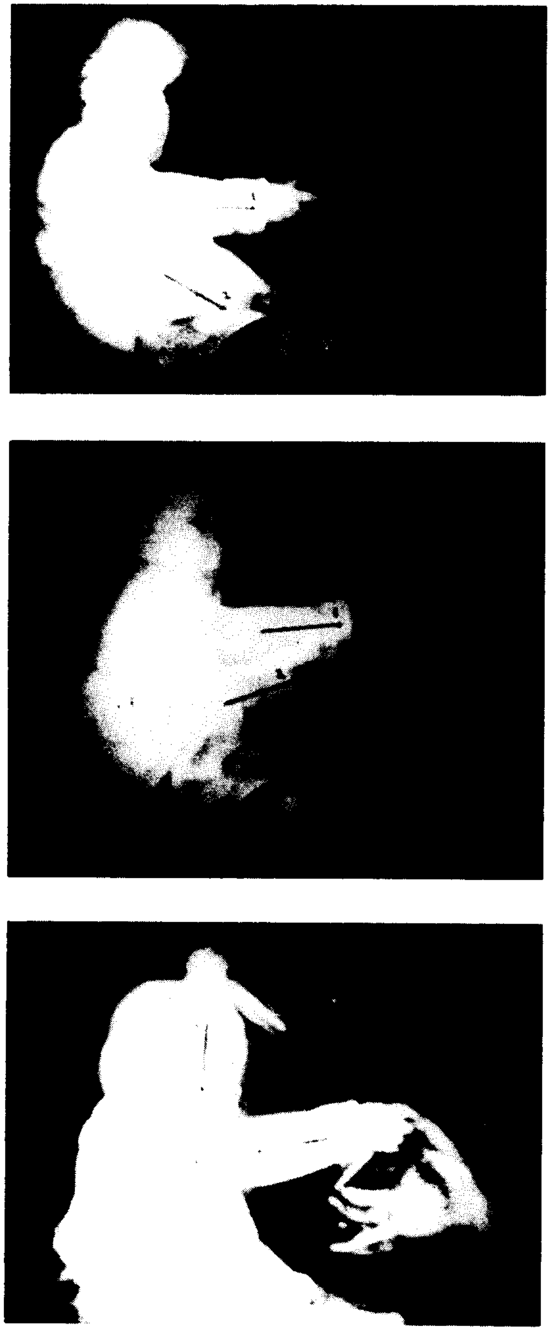


Figure 2. *The top two frames show the response of an infant of 11 months to a normal object, the lower two frames the reaction of the same infant to the visually identical lighter object (item 2b). The rapid grab typical of infants of this age means that the illusory object produces aberrant trajectory rather than a simple drop or elevation*

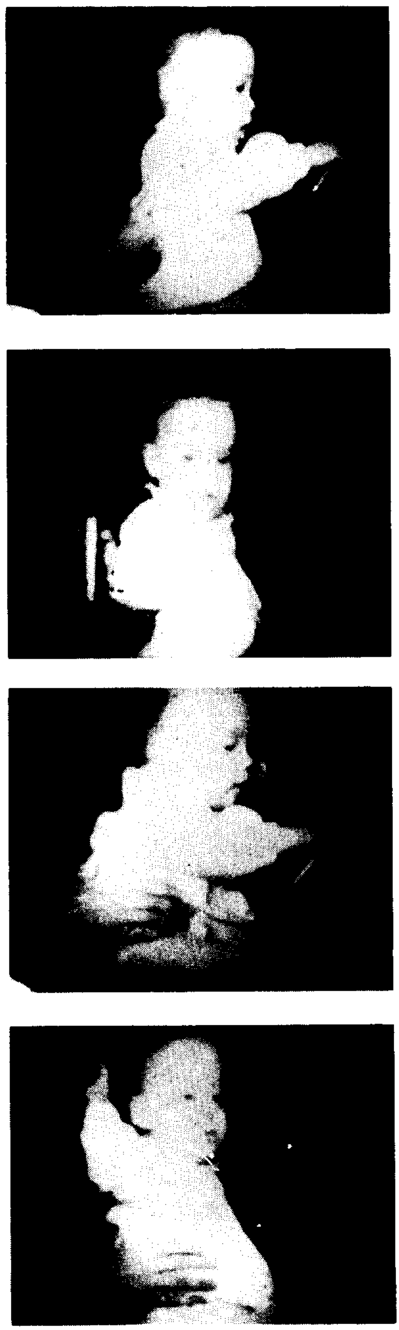
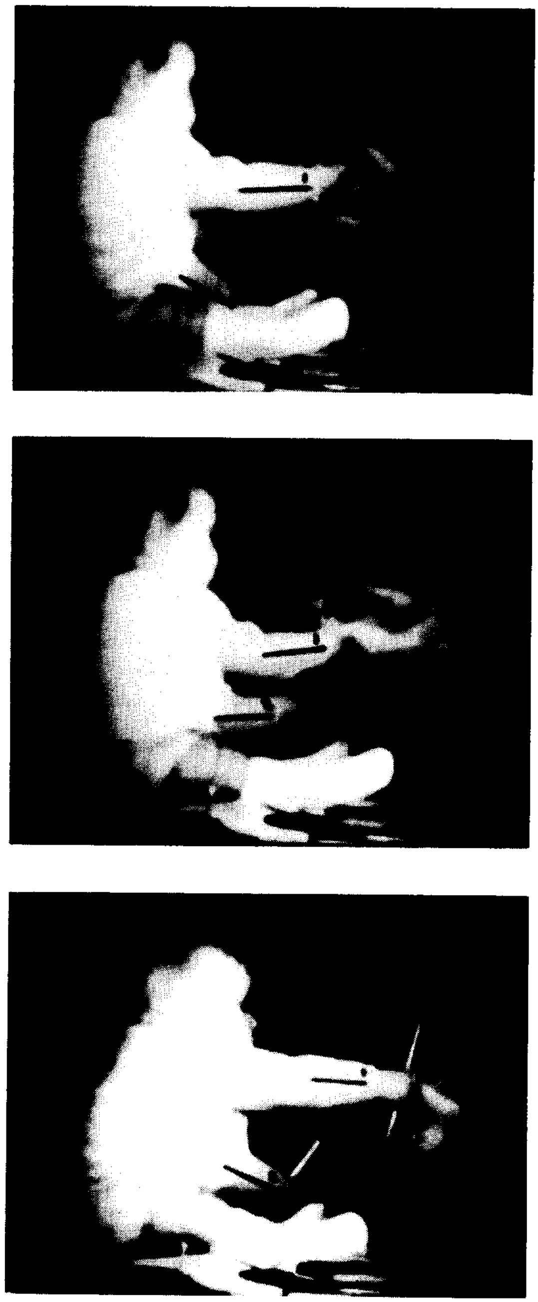


Figure 3. *Each frame shows two arm positions superimposed. Top – response on first presentation of conservation object; center – response on third presentation of conservation object, note diminished arm excursion; bottom – response on first presentation of conservation object after transformation. Note size of arm drop*



3. Experiment 2

3.1 *Subjects*

A total of 30 infants (6 each at 9 months, 12 months, 15 months, 18 months and 21 months) were run through the entire series. A further 24 (12 each at 15 months and at 18 months) were run with the conservation set alone, half with the long-to-short, half with the short-to-long transformation. This was done to ensure that the seriation set was not inducing a conservation error that would otherwise not have occurred.

3.2 *Procedure*

The basic procedure and assumptions of the force of grip experiment were the same as those of the experiment just described. The seriation set consisted of 4 rods each 2 cm X 2 cm, with lengths 2.5, 5.0, 10.0 and 15.0, weighing 45, 90, 180 and 275 grams. The transformable object was a 2 cm X 2 cm X 17 cm rod, weighing 280 grams, hinged in the center. The objects were placed on a table top within reach of the infant. All the rods were cloth covered. Each contained a pressure transducer made of resilistor foam to pick up force of grip. The output of the pressure transducers was recorded on a Beckman polygraph. The polygraph was calibrated so that when no pressure was applied the pens were at their maximum downward deflection. The reading for the minimum pressure necessary to hold each object was determined empirically. The basic measure taken was the initial applied pressure, defined as the maximum pressure applied within 300 msec of contact with the object. This was converted to a percentage error by subtracting the minimum pressure necessary to hold the object from the obtained pressure, dividing it by the minimum pressure and multiplying by one hundred. Our assumptions were the same as before: That anticipation that the same object would weigh the same on repeated presentations would show up as increasingly precise initial applied pressure over the three presentations of an object, that serial anticipation would show up as increasingly precise initial applied pressure with objects presented late in the series, that lack of conservation would show up as a change in the pressure applied to a transformed object which could increase or decrease depending on whether the baby centers on the variation in length or width. Conservation would appear as no effect of transformation in either direction.

3.3 *Results*

The results for the two basic forms of anticipation are shown in Table 4. As can be seen there, sequential presentation of the same object results in improvement at all ages. However, serial prediction does not improve in the same way until 15 months. At this age the improvement for the lightest object is significant beyond the .001 level. For the heaviest object the improvement just escapes significance ($t = 2.42$ $df = 2$ $p < .1 > .05$). In part this negative result is an artefact since the initial response to the heaviest object was better than we would have expected by chance. If we take response to the lightest object as our criterial test, then we can conclude that serial prediction is within the infant's repertoire by 15 months.

Table 4.

% error	Age 9	12	15	18	21
1st presentation of lightest object	400	300	200	200	200
3rd presentation of lightest object	0	5	0	5	0
1st presentation of heaviest object	−20	−30	−18	−18	−18
3rd presentation of heaviest object	12	5	0	0	−5
1st presentation of lightest object after experience with other 3	400	300	10	10	10
1st presentation of heaviest object after experience with other 3	−30	−30	−15	0	5

The basic results for the conservation test are shown in Table 5. There are problems in evaluating these responses. The expectation is that non-conservers will expect the transformed object to be a different weight from itself when untransformed. However we have no *a priori* reason to believe that they will think a particular transformation results in either an increase or a decrease in weight. If half of a group of non-conservers thought that the transformation resulted in an increase and half in a decrease, the mean change could be zero, a result that on the face of it would indicate conservation.

Table 5.

Age months	% error	Last presentation prior to transformation	First presentation after transformation (long-to-short)	First presentation after transformation (short-to-long)
9		−25	25	44
12		−10	30	66
15		−3	−43	97
18		−4	−4	−3.5
21		−5	−4	−4
15*		−10	−45	95
18*		−5	−5	−5

* Group with no seriation pretraining

As can be seen in Table 5 the problem does not arise until the infants are 18 months old. The younger infants did not show conservation behavior. Further, at 15 months infants seemed to equate weight with length, in that the applied pressure was increased when the object was elongated and decreased when the object was shortened. This was true even in the group with no seriation pre-training, in that all 6 infants given the short-to-long transformation increased their applied pressure while all 6 given the long-to-short transformation decreased their pressure. The probability of either result occurring by chance is less than .016. At 18 months, 4/6 infants increased pressure on the short-to-long transformation and 4/6 decreased pressure on the long-to-short transformation. The probability of such a result is .454, virtually chance. Under these circumstances the mean difference is less relevant than a comparison of the two variances. If the infants saw the transformed object as different, we would expect the variance to increase as outlined above. If they saw it as the same object, weighing the same, we would expect the variance to decrease, as the judgments grew more precise. The variance for the last judgment for the 18-month-old inexperienced group prior to transformation was 91.6 whereas the variance for the judgment after transformation was 10.4 ($f = 8.8$, $p < .01$). We can thus conclude that the 18-month-old group showed conservation behavior.

4. Discussion

These experiments indicate that infants develop a behavioral form of weight conservation, the ability to detect that weight is invariant under transformations of the shape of the object whose weight is in question, by 18 months. The sequence of development is the same as that observed at a verbal level in children between 4 and 8 years. It would seem that we are dealing with the first phase of a vertical *décalage* (Piaget, 1941b).

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Résumé

La conservation des poids peut être définie comme la capacité d'affirmer que le poids d'un objet reste inchangé malgré ses transformations morphologiques. On sait, qu'à un niveau conceptuel, cette capacité est acquise approximativement à l'âge de neuf ans.

Le comportement des enfants semblerait indiquer qu'une forme sensori-motrice de la conservation est acquise entre 6 et 18 mois.