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Quantification, Conservation, and Nativism

Quantitative evaluations of children aged two to three years are examined.

Jean Piaget

Mehler and Bever's paper on the cognitive capacities of very young children (*1*) presents some new and interesting data on the development of quantitative evaluations from the age of 2½ years onward. Although, unfortunately, these novel results have hardly been subjected to any analysis regarding the possible factors at work, and although they have nothing to do with conservation (whatever the authors may say), they yet are suggestive of a useful complement of information on the development of quantification. In addition, Mehler and Bever's thesis regarding the role of innate structures—like Chomsky's (*2*) which inspired it—provides an effective antidote to the exaggerated simplifications that usually form part of learning theories; but having chosen the other tack, they encounter a series of new problems which it may be instructive to investigate, the better to avoid the Charybdis of empiricist learning as well as the Scylla of rationalist nativism.

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Quantitative Evaluations Based on Correspondence, Order, and Crowding

At the level of operatory conservation, children judge two collections to be equal or unequal by looking for a one-to-one correspondence between their elements (even if one collection covers a larger area or is spaced out with greater intervals). At an earlier stage, children judge one collection to be more numerous than the other (or to contain "more" elements, even if they admit that in counting the elements one gets the same number in each) as soon as the line formed is of greater length. How should this length factor be interpreted?

Mehler and Bever analyze this factor briefly but inadequately, since they seem to believe that everything is taken care of once "perception" of length is invoked, as if this perception were sufficient to suppress momentarily an otherwise correct notion of numerical quantity. Evaluation by length is actually based on an ordinal quantification which is already of a conceptual nature, and which is far more complex and general than the experiment on number alone would lead us to suppose. Research on the concept of length (of paths, for example) has shown that, at the level of development in question, "longer" means "going further," not because of a dominance of perception, or because of a verbal or semantic confusion, but because the first quantifications that become possible before the synthesis of number (a synthesis of order and inclusion) and that of measure (a synthesis of partition and displacement) are based on an order of the points of arrival. This may be explained by the following. Before the child becomes capable of reversible operations, his thinking proceeds by "functions" in the modern sense of "mappings" (one-way mappings) or of "ordered couples." Psychologically, functions are the expression of action schemes, and every action (particularly an action whereby a certain distance is covered) is a series of ordered movements which will come to an end (at the point of arrival). This concept of "function" explains the dominance of ordinal considerations that underlie quantitative evaluations of and by length between 3 to 4, and 6 to 7, years of age.

But the results obtained by Mehler and Bever seem to show that prior to these purely ordinal evaluations there exists between 2 years, 6 months and 3 years, 2 months an even more primitive mode of quantitative evaluation, which with their display, Fig. 1*b*, leads to 100 percent correct answers. In the light of what we have said about ordinal structures, let us try to understand what kind of factors may be involved in these reactions. In the first place, we should not forget that, as far as space is concerned, children start with topological structures based on proximity, separation, enclosure, and frontiers (interiority or exteriority), before they consider length or even rectilinearity; in a recent work, Laurendeau and Pinard

(3) have verified by hierarchical analysis the consistency and the anteriority of these topological intuitions as compared with Euclidian metrics.

This being so, it is possible to hypothesize that in the case of Mehler and Bever's (1) (Fig. 1) display—six elements crowded on a line 5 inches (13 cm) long, and four elements spread out over 8 inches (20 cm)—the subjects that had not yet reached the stage of evaluation by length (ordinal comparison of points of arrival) used an even more primitive mode of evaluation, which would be a topological evaluation based on a notion which might be called a notion of "heaping" or "crowding." In other words, when a child compares two figures or two rows in a simple topological way (roughly analogous to homeomorphy) he will get the impression that the short row is more "heaped" or more "crowded" than the long one, in the sense that in the former the elements are nearer one to another in relation to the total figure. To verify this hypothesis a number of experiments are necessary (4, 5), and we will discuss some of them below.

Against the concept of "crowding" it can be objected that with reference to Fig. 1*c*, 22 answers out of 32 indicated that the children saw the longer row of six spread out elements as containing "more" than the short row of four crowded elements. But this objection is not decisive, for several reasons. In the first place, a certain number of children (if we understand the authors correctly) still said that there were "more" in the short row of four elements. In the second place, the fact that only 22 out of 32 answers were correct (with only seven subjects out of a total of 16 giving consistent answers) shows that this situation arouses a conflict and is more complex than siuation *b* (Fig. 1*b*). It is easy to understand the origin of this conflict—in Fig. 1*b*, the ratio of the lengths is 8 to 5, that is to say, the long row is only 1.6 times longer than the other, whereas in Fig. 1*c*, the ratio is 25 to 5, that is to say, the long row is five times longer than the other. Subjects at an intermediate stage between evaluation by "crowding" and evaluation by length are obviously more apt to be struck by length in Fig. 1*c* than in Fig. 1*b*, and since *c* is the long row containing six elements (against four in the short row) evaluation by length happens in fact to give the correct answer. However, other experiments are necessary to dissociate these factors. Here are some of our results.

New Experiments

We interviewed 29 children between the ages of 2 years, 3 months and 3 years, 10 months (6), with Mehler and Bever's techniques and also with our technique of presenting two rows of four or six elements in optical correspondence, which are then spread out or crowded together in one of the rows. But, unlike Mehler and Bever, we not only presented unequal collections, but also equal collections where one row had its elements spaced out (length) and the other had its elements close together (heaping or crowding).

Technically the experiments are difficult, since there are perturbing factors which are not mentioned by Mehler and Bever, but which are of importance. (i) Some subjects always consider the row which is nearest to them as containing "a lot" of elements, and the row which is further away as containing "a little" or "not a lot." (ii) Preliminary experiments showed that many very young children do not understand the terms *"plus"* (more) and *"moins"* (less) in any consistent way, whereas *"beaucoup"* (a lot) and *"peu"* (a little) or *"pas beaucoup"* (not a lot) give rise to more consistent answers. We used both types of expressions. (iii) The first meaning attributed to "more" by subjects of up to 3 years, 6 months is that of adding to one collection, and not that of comparing two collections (A > B) without either of them being modified. (iv) Some subjects even say "a lot" for any collection on which the experimenter acts (whether he shoves elements togther, or whether he adds other elements) and "a little" for the collection that remains undisturbed. This is important since in Mehler and Bever's experiment it is always the more numerous row that is manipulated.

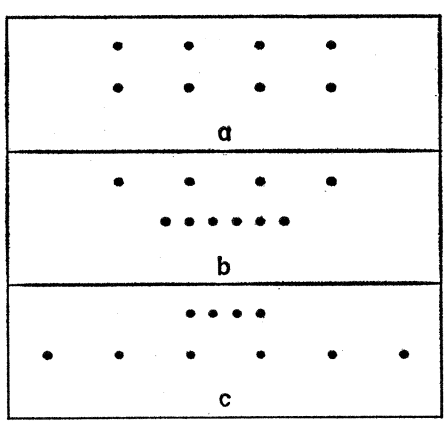

Fig. 1. The length of the rows in (*a*) was 7 inches (18 cm) for M & M's and 8 inches (20 cm) for clay pellets; in (*b*) 7 and 3 inches (18 and 8 cm) for M & M's and 8 and 5 inches (20 and 13 cm) for clay pellets. There was a 1⅓-inch (3-cm) space between each of the four clay pellets and a 2-inch (5-cm) 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. [Taken from Mehler and Bever (1)]

Despite these difficulties, the results of our experiments are clear enough except for eight subjects between 2 years, 3 months and 3 years, 0 months, who are totally inconsistent in their answers; that is, they give different answers to the same question asked several times in the same situation. We noted the following answers.

1) With rows containing an equal number of elements (four and four, or six and six), where one row is spread out and the other is crowded, 84 answers indicate one of the rows as containing "more" or "a lot" of elements; not one subject said that the rows were equal in number. At this level there can consequently be no question of conservation.

2) With regard to rows with unequal numbers of elements (four against five, six, seven, or eight), we find 28 correct answers ("a lot" for the row with more elements) and 29 incorrect answers (one subject even considered 4 > 8 because the four elements were widely spread out).

3) With regard to equal rows with optical correspondence (four to four or six to six) the youngest subject who understood and expressed the equality was 3 years, 4 months old (she said, "There are a lot here just like there"). Otherwise, subjects answered "yes" just as much to the question "Is it the same?" as to the question "Is there more here?" As to the criteria the children used for their evaluations, (i) from 3 years, 6 months onward (and, it seems, from the moment the optical correspondence begins to be understood in terms of equal quantity) considerations of length began to dominate; (ii) we did not find any subjects who judged only on heaping or crowding; but (iii) eight out of 15 subjects between the ages of 2 years, 3 months and 3 years, 2 months and one subject of 3 years, 9 months alternated between the crowding criterion and length. In verbal judgments ("a lot" as against "not a lot") as well as when the child is asked to choose a row of candies, four or six crowded elements are sometimes taken to be "more" than four or six spread out elements. Crowding thus

does lead to quantity judgments, and this is more frequent at the earlier age than at the age of 4 to 5, which we studied with Szeminska (*5*).

Conservation of Number

Mehler and Bever's experiment has nothing whatever to do with conservation, and I cannot understand why the authors continually talk about conservation, or why they conclude that the answers that coincide with the correct numerical quantities exhibit conservation (*7*). They probably think that since the usual obstacle to number conservation is evaluation by length, it suffices to show that children from 2 years, 6 months to 3 years do not evaluate quantity by length to conclude that they possess the notion of conservation. However, there is no getting away from the need to agree on terminology. We call "conservation" (and this is generally accepted) the invariance of a characteristic despite *transformations* of the object or of a collection of objects possessing this characteristic. Concerning number, a collection of objects "conserves" its number when the shape or disposition of the collection is modified, or when it is partitioned into subsets.

Now, in Mehler and Bever's experiment there never are any transformations of equal collections. A subject of 3 years old who in situation *b*, Fig. 1, says that there are more elements in the short row of six than in the long row of four, may maintain the same judgment if the two rows are given the same length; but conservation of equality is not proven by such conservation of inequality. The former can be shown only if two rows of equal number are presented and one row is then spread out or crowded; or at least, if two rows of unequal length but equal number are presented without modification. In these situations our results were negative (as already mentioned) for subjects between 2 years, 6 months and 3 years, just as they were for subjects from 3 to 4 years of age.

We insist on this problem on conservation because Mehler and Bever curiously end their paper by saying that nonconservation "is not a basic characteristic of man's native endowment," as if I had ever said anything to the contrary. The natural tendency of young children, evidently, is to conserve as long as they are not confronted by facts which they do not expect, and whose inexplicability leads them to change their opinion. We have, for example, described (*8*) the reactions of young children (well before Bruner applied this technique) when the content of a low, wide glass is poured into a tall, narrow glass behind a screen. Before they have seen what actually happens these children expect that there will still be "the same amount to drink," that the quantity of liquid will be conserved, and the level of the liquid will be conserved as well (in fact, the level of the liquid constitutes the measure of its quantity from an ordinal point of view). In these cases we speak about pseudoconservation, since these subjects conserve too much, and therefore incorrectly. Only after having seen that the level goes up in the narrow glass will these subjects deny conservation of quantity and opine that the quantity has increased because the level has changed; yet, to repeat the point, this is not simply due to a perceptual strategy, but to the fact that, in the absence of other means of measurement, an ordinal evaluation by level necessarily leads to this conclusion.

In general, children expect conservation, but since they cannot know beforehand what will be conserved and what will not be conserved, they have to construct new means of quantification in every new sector of experience. The inadequacy of the means of quantification explains nonconservation, and it is worth noting that nonconservation therefore indicates an effort to analyze and to dissociate variables; very young children and severely mentally retarded subjects pay no attention to these variables, whereas the older, normal children pass through a stage of nonconservation as they reorganize relations which they cannot yet grasp in full.

Role of Innate Structure

The development of cognition and especially the construction of means of quantification (initial pseudoconservation, followed by nonconservation, and finally by operatory conservation) consitute a coherent whole in which Mehler and Bever's observations will find their place when new facts have clarified the interpretation given to their results. In the meantime, it is necessary to discuss the solution proposed by the authors, that is to say, the hypothesis that an innate kernel furnishes an immediately valid schema of quantitive evaluation, which later deteriorates because of imcomplete performances or misleading perceptual strategies, and which finally brings about a return to the correct, innate ideas.

The explanation of cognitive behavior by means of innate ideas is, in general, a facile and rather lazy solution, which accordingly has always been criticized by empiricists. However, after the excesses of explanation by learning alone, a return to nativism is to be expected, but with the attendant risk of lapsing into its traditional faults, that is, nativism cannot explain the details of the (primarily biological) mechanisms that are at work. What is the way out of this dilemma?

The merit of the solution proposed by Mehler and Bever—and this aspect of their nativism I find particularly pleasing—lies in the fact that, in contrast with all traditions of classical rationalism, they call upon an innate mechanism that is so poor and so fragile that it manifests itself victoriously only between the ages of 2½ and 3 years, after which it fails in its task until new strategies and performances allow the observer to rediscover its traces at the end of early childhood. When nativism presents itself in such a modest way, it is easy to discuss and to weigh its advantages and disadvantages.

In the first place, it is clear that if the "innate ideas" of numerical quantity can be so easily conquered or counteracted by bad "perceptual strategies" at the stage of nonconservation they cannot consist of a real structure with a hereditary, biogenetic programmation; they can be no more than an innate form of functioning. When biologists talk about a specific innate structure, they consider it to be programmed in the genetic information of the DNA, and this programming of ulterior syntheses is sufficiently resistant to conquer the perturbing effects of environment, if the organism survives. The innate ideas of Mehler and Bever remain dependent upon external situations, that is to say, they "function" well or badly according to these situations. If innate "functioning" is what they are talking about, it is easy to agree with them, because, evidently, an innate, intelligent functioning is necessary to arrive at the construction of numbers (it is impossible, for example, to bring about such functioning in the brain of a subject with severe mental defect). I have always maintained that logico-mathemental structures are not derived from language (an empiricist hypothesis) but from the general coordination of actions, with their permanent functional mechanisms of ordering (order of movements), embedding (of a subscheme into a total scheme, for example), establishing correspondences, and equivalences. All these factors intervene in the construction of numerical quantities, and they obviously suppose an innate neurological and organic functioning; as long as only such functioning is involved, without structural hereditary programmation. I accept the necessity of an innate point of departure.

This being so, a second problem immediately arises: What are the mechanisms which are necessary for this innate functioning to proceed toward the completed structure? In other words, is it necessary to suppose a progressive building up of structures which were not initially contained in the functional kernel? On this point Mehler and Bever's arguments seem equivocal; with regard to the psychological problem of number (we are not talking about linguistics), they continuously oscillate between a transformational functionalism and a preformational structuralism. They argue as if the innate kernel consisted nevertheless of some sort of preformed structure, which becomes veiled by bad "perceptual strategies" or by unsuccessful "performances," but which reappears when better circumstances permit.

We would like to ask two further questions. What are the conditions that cause the strategies employed sometimes to counteract, and sometimes to favor, this innate kernel? And once the obstacles have been overcome, is the final structure the same as the structure that existed at the age of 2½ to 3 years, or has it been transformed and enriched, and if so, why? These two questions are closely linked to one another and dominate the problem mentioned earlier: if the final structure is richer than the initial one, a construction must have taken place, and preformation is not the answer; moreover, the intermediate strategies must all have contributed to this construction and cannot be considered as good or bad in function of a (falsely) absolute model, since they constitute the necessary stages for the completion of this construction.

What is lacking in Mehler and Bever's argument is the concept of productive actions and of the operations which stem from these actions. The fundamental characteristic of operations is that they produce novelties (empiricists try to explain this fact by exogenous learning) by means of "reflexive abstraction" from actions at an earlier stage (and it is this endogenous process that presupposes a functional kernel with innate roots). Mehler and Bever only consider, on the one hand, what is innate, and on the other, perceptions and performances. Thus they cut the link between the subject and exterior reality, which leads them to consider the former as sometimes a winner, sometimes a loser. By constrast, the concept of operations explains, and is the only way to explain, how an initial functional kernel yields completed structures, that is, by a series of self-regulations and equilibrations in which even the errors play a functional success-promoting role.

To conclude, Mehler and Bever invoke an innate structure which supposedly accounts for early correct answers (we have interpreted these answers in a different way) and for the final successes but which does not explain why the structure is overpowered so easily during the intermediate stages, or why the final structure is richer than the initial one. I maintain that when these facts are explained, the concept of an "innate structure" becomes superfluous, that an innate functioning is sufficient. I maintain above all, that when the rather Manichaean notion of good and bad structures is replaced by an adequate theory of progressive equilibration starting from self-regulation, the idea of construction will prevail over that of preformation; for, as the great biologist Dobzhansky has said, though predetermination is impossible to disprove, it is on the contrary (and I would add, precisely for that reason) completely useless (*9*).

References and Notes

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2. For example, N. Chomsky, *Aspects of the Theory of Syntax* (M.I.T. Press, Cambridge, Mass., 1965).
3. M. Laurendeau and A. Pinard, *Les premières notions spatiales chez l'enfant* (Délachaux et Niestlé, Neuchâtel, in press).
4. In our previous experiments with A. Szeminska (see ref. *5*), not all our subjects without conservation between 4 and 5 years of age considered the longer row as containing more elements; some (and these were not the most advanced) considered that there were more elements in the crowded row. Mehler and Bever's results now suggest that such answers show a residue of an earlier stage at which the criterion of quantification is either crowding or sometimes crowding and sometimes length.
5. J. Piaget and A. Szeminska, *La genèse du nombre chez l'enfant* (Délachaux et Niestlé, Neuchâtel, 1941); translation, *The Child's Conception of Number* (Routledge and Kegan Paul, London, 1952).
6. Five subjects from 2 years, 3 months to 2 years, 7 months; ten subjects from 2 years, 8 months to 2 years, 11 months; nine subjects from 3 years 0 month to 3 years, 4 months; and five from 3 years, 5 months to 3 years, 10 months; as well as three subjects from 4 years 0 month, to 4 years, 1 month, whom we have excluded, though reactions were analogous to those of the younger subjects.
7. It may be worth pointing out that misuse of the term "conservation" also occurs in the work of other authors. Bower, in his admirable experiments on newborn babies, seems to have proved (but his results will have to be confirmed by others) that at the end of the first week of life the baby already recognizes an object which has been hidden behind a screen and which is then shown to him again; or at least, that the baby distinguishes this object from another one. However, this only proves that recognition is a very early phenomenon, which I have never denied, it does not tell us whether for the baby the hidden object continues to exist when it is placed behind another object, or whether the object has momentarily ceased to exist, like an image that can disappear and reappear and then be recognized as having been seen already. The hypothesis of conservation would suppose a substantification of reality and an organization of space; recognition by itself does not indicate whether this organization is present or not, or even whether such organization is possible or not at this age. The hypothesis that the newborn baby's universe consists of tableaux which disappear and reappear is much simpler and just as compatible with very early recognition. With regard to the early "tunnel-effect" this phenomenon has to be dissociated from a simple oculocephalogyral reflex, a problem for separate discussion elsewhere.
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Reply by J. Mehler and T. G. Bever

Our research has been focused on the cognitive capacities of the 2-year-old child. We reported that the 2-year-old performs better than the 4-year-old in judging the relative quantity of rows of clay balls (*1*). (The stimuli are represented in Fig. 1*b* of Piaget's discussion.) Since Piaget developed the theoretical problem as well as the general techniques used, there are many points of agreement between our initial paper and his critique, and some points that remain to be clarified (compare *2* and *3*).

With respect to the experimental issues, Piaget suggests that the young child responds to the relative density or "crowding" in the shorter row, not to its relative numerosity. We have recently used numerically equal rows

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