Cognition, 7 (1979) 7 (1979) 125 -144
©Elsevier Sequoia S.A., Lausanne – Printed in the Netherlands

Piaget's theory of space perception in infancy*

ANAT NINIO

The Hebrew University, Jerusalem

Abstract

Piaget's theory of space perception in infancy is presented in the format of a hypothetico-deductive system. Eleven hypotheses are defined, regarding the perception of the agent of visual change; shape and size constancy; depth; and the perception of higher-order relationships among spatial elements. The proof Piaget offers for each hypothesis is presented in the following steps: behavioral evidence, interpretation in terms of inner states; inferences and generalizations. Presuppositions underlying the arguments are explicated. Critical notes are inserted whenever appropriate. Some general conclusions are briefly discussed.

Introduction

Is the infants' perceptual space qualitatively different from that of adults? This claim has been put forward by Piaget and his collaborators in two seminal volumes (Piaget, The child's construction of reality, 1955; and Piaget and Inhelder, The child's conception of space, 1956), and since then widely accepted. It is only very recently that experimental evidence directly bearing on this question has started to accumulate, and it has not been unequivocal. For instance, neuropsychological research has shown that, in animals, many higher-order perceptual forms and relations, as well as lower-order ones, are apprehended directly through "wired-in" recognition systems, which are in all probability inborn. These relations and forms include lines, angles, straightness and convexity, orientation of lines, relative depth, parallelism, perpendicularity and corners (Maturana et al., 1960; Hubel and Wiesel, 1962; Barlow et al., 1967, Pettigrew et al., 1968). It is very plausible that the same sort of inborn mechanisms operate in humans; for instance, Bower (1968) showed that newborn infants have stereopsis. This implies that the

*The author wishes to thank Amia Lieblich, Dan Frankel and Zeev Klein for their helpful comments. Requests for reprints should be sent to Anat Ninio, Department of Psychology, The Hebrew University, Jerusalem, Israel.

perceptual space of humans might not undergo that series of qualitative changes which Piaget inferred from the many observations on his children.

It was felt that alongside the experimental studies on infant perception there was room for a reexamination of the original Piagetian claims. This paper attempts to contribute to this effort.

Piaget's work on space is fairly central to his general theory of intelligence, and as such, it is developed in great detail. Nevertheless, neither Piaget nor any of his summarizers provide a concise and systematic résumé, which will at the same time contain the details necessary for a critical evaluation. The scope of the summarizers is usually too wide to fill these requirements. Flavell (1963), Ginsburg and Opper (1969), Hunt (1961), and Wolff (1960), for instance, allot to the discussion of early space only about three pages, on average.

This paper represents an attempt to fill this need, namely to present Piaget's work on early perceptual space in a concise and systematic form. The method adopted is similar to that of Wolff (1960), namely, spelling out in full the steps of the Piagetian argument, and if necessary, explicating the implied.

Piaget's method of presentation is a version of the hypothetico-deductive system. He starts out with a description of some observations on infant behavior in specified situations. He then interprets the infant's overt behavior in terms of inner states of consciousness, wishes, expectations, knowledge, perception and concepts. From the sum total of these interpretations Piaget proceeds to deduce a general statement about the infant's cognitive capacities. In some cases he tests the limits of his generalization with additional observations, or on data collected on another child. Most inferences rest upon presuppositions, not explicit in the text.

In this paper Piaget's main statements about the infant's space are defined as formal hypotheses. The proof he offers is followed through from observational evidence to conclusion, in the following steps:

(a) *Evidence:* mostly consists of the description of observational situations (usually quasi-experiments set up by Piaget) and the infant's responses or other behavior. The description is usually generalized across a number of similar situations, unless the differences are such as to warrant a separate presentation.

(b) *Interpretation* of the observed overt behavior in terms of inner states of consciousness, abilities etc. in the infant.

(c) *Inferences:* several steps of inference are usually drawn from the observations and their interpretation, each inference logically deduced from its predecessor.

(d) *Presuppositions:* the set of necessary presuppositions linking each step in the argument to its predecessor is explicated. Presuppositions are presented here whether explicit in Piaget's writings, or inferred from his argument.

(e) *Notes* are inserted whenever the logic of progression from one step to its successor seems to me to be incorrect.

The Notes represent the sole attempt at critical evaluation. No novel evidence whatsoever is reported; this study aims to examine the logical consistency of the Piagetian system from its own premises. However, the reader is in possession of psychological knowledge which has accumulated since the first appearance in print of the two space books, in 1937 and 1948. The critical Notes appeal to this knowledge, at least implicitly.

Full reference is given for observations and statements; for the former both serial number of observation and page number are given. The names of the two main space books are abbreviated: CS refers to "The child's conception of space" (Piaget and Inhelder, 1956), while CR refers to "The child's construction of reality" (Piaget, 1955). Age at observation is not given. Only visual space is discussed, following Piaget's emphasis on the visual system.

Although the development of space is intimately connected to the development of sensory-motor intelligence, it was considered possible and in the best interests of clear presentation to present Piaget's ideas regarding infant perceptual space independently of the general system. In concrete terms this means that every Piagetian hypothesis and observation on infantile perceptual space has been included here indiscriminately, regardless of the sensory-motor stage it is related to.

A further simplification in presentation was achieved by omitting all reference to Piaget's theory of groups. It was felt that this omission did not seriously hinder the achievement of this paper's limited aims.

Piaget's Theory

Before turning to the actual hypotheses, it should perhaps be recalled that for Piaget there is no clear separation between perceptual and intellectual processes. Indeed, perception is "not a primary element independent of intelligence", but, rather, "the result of intellectual activity" (CR, p. 212). The way in which the infant perceives space is, therefore, directly influenced by the ways in which he conceives of space, and the two are indistinguishable. Or, in Piaget's words, "perception implies a sensory-motor schema which brings the sum-total of previous constructions to bear on the actual situation" (CS, p. 15). Therefore, in infancy, prior to the appearance of representation, perception of space is identical to conception of space. With the development of representational and operational intelligence, it is possible to think of objects in their absence and thus perceptual and conceptual

space can be distinguished from each other (CS, p. 17). Such a distinction is impossible for the first period which is the subject-matter of the present exposition.

What are, then, the characteristics of the infant's spatial universe? It has four major characteristics, best expressed in the negative. The infant's space is not objective, not populated by objects of constant shape or size; not three-dimensional and does not contain relationships of higher than topological order among its elements.

These main themes might be expressed in the following more detailed and more precise form:

A. The infant has no means of distinguishing the source of change in the shape of objects, namely, he cannot specify whether the visual change has resulted from movements of the object or from movements of his (the infant's) body (CS, p. 12).
B. The infant has no means of distinguishing the source of change in the shape of objects, namely, he cannot specify whether it has resulted from a change of state or from a change of position of the object (CS, p. 9; CR, p. 103).
C. A change in the perspective of the object is perceived by the infant as an actual transformation of the object (CS, p. 11).
D. There is no shape constancy (CS, p. 6).
E. There is no size constancy (CS, p. 5).
F. The infant perceives space at the first period of his life as a fluid mass without depth (CR, p. 145).
G. At a later period in infancy, space becomes differentiated into two zones, "near space" and "far space" (CR, pp. 143–145).
H. The differentiation between "near space" and "far space" is not that of depth (CR, pp. 143–145).
I. The objects in "far space" appear to the infant diminished and distorted by perspective (CR, p. 143).
J. "Far space" is undifferentiated into depth planes (CR, p. 145).
K. Spatial relationships of projective and euclidean (i.e. higher than topological) order are not perceived (CS, p. 6).

In the following the evidence Piaget marshalls for each of these hypotheses will be presented and the connection between each piece of evidence and the hypothesis made explicit.

A. Hypothesis: The infant has no means of distinguishing the source of change in the shape of objects, namely, he cannot specify whether the visual change has resulted from the movements of the object or from the movements of his (the infant's) body (CS, p. 12).

Evidence:
1. Observations on the behaviour towards vanished objects or unseen parts of objects;
2. Observations on the imitation of facial gestures;
3. Observations on shaking of head and body while looking at hanging objects.

1st Evidence: Observations regarding infant behavior towards vanishing objects or parts of objects were made in ten different situations, described below. Also described is the infant's behavior in each of the situations.

Situation a: The adult moves within the visual field of the infant, then leaves it. The infant follows the movement with his eyes up to the adult's disappearance and keeps watching the point of disappearance (CR, obs. 2, p. 13).

Situation b: The adult appears and disappears repeatedly at one point in the infant's visual field. The infant keeps watching the point of disappearance (CR, obs. 2, p. 13).

Situation c: The infant looks at a stationary adult, turns away, then turns back to look at the adult several times (CR, obs. 5, p. 11; obs. 12, p. 18).

Interpretation of infant behavior in situations a, b and c: The infant expects the adult (= object) to reappear if he repeats the *last* act of accommodation which has been accompanied by the sight of the object (CR, p. 13).

(*Note:* It should be noted that this is a *rational* expectation, usually fulfilled, for instance in situations b and c, above. It is unclear what alternative rational search behaviors, if any, are possible for an infant who is confined to a bed. Searching for the adult anywhere else in the immediate visual field would be incorrect, since the adult has been observed leaving it. An immobilized adult would behave very similarly in these circumstances.)

Situation d: The adult appears at successive positions A, B, and C, ordered from right to left, then disappears at extreme left (C). The infant looks at A (CR, obs. 71, pp. 118–119).

Situation e: The adult opens a door, interacts with the infant, crosses the room and disappears from the infant's sight. The infant looks at the direction of the door (CR, obs. 72, p. 119).

Interpretation of infant behavior in situations d and e: The infant expects the object to reappear if he repeats the *first* act of accommodation which has been accompanied by the sight of the object (CR, p. 119).

(*Note:* It should be noted that in the circumstances of situation *e* this seems to be a rational expectation, since the adult did in fact reappear at the door another three times (CR, obs. 72, p. 119).)

Inference: The infant conceives of the displacements of things as extensions of his own activity (CR, p. 102) or as being at the disposal of his activity (CR, p. 20), not as external autonomous events. Moving objects are not considered as being animated by an independent motion (CR, p. 168), nor as capable of following an autonomous trajectory independent of the subject's action (CR, p. 168).
(*Note:* Piaget does not attempt to distinguish between those situations (such as in *a* to *c* above) in which the infant excepts the object to reappear in the last position it has been seen, and other situations (such as *d* and *e* above) in which he expects the object to reappear at the first place seen. Analysis of the situations Piaget reports reveals that the child's guesses are anything but random. In fact he guesses perfectly (in the three situations for which the relevant information is given) the place in which the adult will reappear. As noted above, in situations *b* and *c* the adult did in fact reappear to the most recent position in which he had been seen, while in situation *e* he reappeared at the initial position three times.

Not only do the infant's expectations seem to be rational but, as pointed out earlier, there is no other search behavior which would be as rational as the ones he actually adopts. Piaget (CR, p. 11) claims that if the infant had an object concept, he would search around with his eyes or otherwise change his perspective. This criterion is unacceptable. Since the potential visual field of the infant is constant, restricted and defined by what he can reach with eye and head movements, and since he has just seen the adult *leave this field,* it would be irrational if he searched for the adult anywhere *inside* the same field (since he is bodily restricted, he cannot change the visual field).

To summarize, the infant's behavior in situations *a* to *e* seem to point to the following conclusions. First, that the infant can make inferences about the adult's behavior around him and is able to predict quite accurately in a given situation where the adult will reappear in his visual field. Secondly, that he understands that his visual field can be entered only at specific "ports" of exit and entrance, such as doors, edges of furniture, etc., and not anywhere else. These expectations and pieces of knowledge are rational and ecologically sound, and seem to disprove the idea that infants lack an objective space.)

Situation f: The adult moves an object horizontally at the infant's eye level. The infant loses sight of it, continues his pursuing movement and recaptures the sight of the object (CR, obs. 11 and 12, pp. 17–18).

Situation g: The adult lets an object fall from his hands, held above the infant, in such a way that the infant can see the beginning of the movement.

The infant follows the fall of the object or searches for it on the floor beneath the adult's hands (CR, obs. 6, 8, 9; pp. 14–16).

Situation h: The adult lets an object fall from his hands, held above the infant, in such a way that the infant cannot see the beginning of the movement. The infant tends to look at the adult's hands or at the (empty) space where the object had been held previously (CR, obs. 6, 8, 9, pp. 14–16).

Interpretation of infant behavior in situations f, g and h: The infant expects a rapidly moving or falling object to be continuing its trajectory if he loses sight of it momentarily; he expects the object to reappear if he extends the last act of accommodation which was accompanied by the sight of the object (CR, pp. 19–20).

(*Note:* It should be noted that this expectation is rational, namely, rapidly moving or falling objects can in fact be visually recaptured if the last pursuing movement is extended or continued.)

Situation i: The adult covers (obscures) an object with a screen (cloth, hand). The infant does not uncover it (CR, obs. 7, p. 15; obs. 22–25, pp. 28–32; obs. 28–32, pp. 36–40).

Situation j: The adult rotates an object so that the infant is presented with an unfamiliar face of it. The infant will not rotate the object so that its familiar (or desired) part faces him unless he can see some of the familiar part. For example, he will not rotate a reversed feeding-bottle (presented with the bottom facing the infant) unless some part of the nipple is visible (CR, obs. 77, p. 124–125; obs. 78 and 78a, pp. 126–128).

Generalization of infant behaviors in situations a to j (1st evidence): When neither the repetition of previous accommodations nor their extension brings about the reappearance of the object, the infant is unable to search for it by inventing new procedures (CR, p. 24, p. 43, p. 168).

Interpretation: The infant conceives of the displacement of things as extensions of his own activity (CR, p. 102), or as being at the disposal of his activity (CR, p. 20), not as external autonomous events. Moving objects are not considered as being animated by an independent motion (CR, p. 168), nor as capable of following an autonomous trajectory independent of the subject's action (CR, p. 168).

(*Note:* It is very unlikely that the infant interprets every movement in his environment as one of his own making. There must be many occasions, such as an adult leaving the room, when the object moves against the will of the infant. This point is further discussed on p. 139).

Inference: The movements of objects and movements of self do not exist as two separate conceptual categories in the child's thought. (See Note above).

Inference: Since the infant has no means of distinguishing the movements of an object from his own movements of obtaining the perception, he cannot, by necessity, distinguish the source of change in the shape of objects, namely, he cannot specify whether the visual change resulted from movements of the object or from movements of his (the infant's) body. (Hypothesis A proven.)

(*Note:* In all nine situations comprising the 1st evidence on Hypothesis A the infant's behavior is observed during search for vanished objects. There is a basic incongruity in inferring from data collected exclusively in the absence of objects (i.e., search) to perceptual processes occurring in the presence of objects (i.e., specifying the agents of visual change.) There remains always the possibility that regardless of the plausibility of the argument, the two processes are governed by different laws and are essentially independent.)

2nd Evidence: The infant cannot imitate facial gestures (Piaget, Play, dreams and imitation in childhood, obs. 17–18, p. 27–29).

Inference: The infant does not have visual knowledge of his own face (CR, p. 110).

(*Presupposition:* Visual knowledge of one's own face is a necessary and sufficient condition for the imitation of facial gestures.)

Inference: The infant cannot perceive (or imagine) the movements of his own eyes and head (CR, p. 110).

(*Presupposition:* Visual knowledge of one's own face is a necessary and sufficient condition for the perception of the movements of one's face.)

Inference: The infant does not conceive of himself and his movements as existing independently of the perceived world (CR, p. 108).

Inference: Since the infant does not differentiate between himself and the world, he cannot by necessity distinguish between sources of change in the shape of objects, namely, he cannot specify whether the visual change resulted from movements of the object or from movements of his own body. (Hypothesis A proven.)

3rd Evidence: The infant shakes his head and body and simultaneously looks at hanging objects (Piaget, The origins of intelligence in children, obs. 112, 115, 118, pp. 200–205: CR, obs. 88, p. 158–159).

Interpretation: The infant wants to make the distant object move by his own movements (CR, p. 160–161).

(*Note:* Alternative interpretations are more plausible, e.g., that the infant investigates the effect of his movements on the visual scene.)

Inference: The infant believes that displacements of objects are at the disposal of his activity, and an extension of this activity (CR, p. 20, p. 117).

Inference: The infant has no means of distinguishing the source of change in the shape of objects; namely, he cannot specify whether the visual change resulted from movements of the object or from movements of his own body. (Hypothesis A proven.)

(*Note:* The basic premise on which the proof of Hypothesis A rests is that the infant cannot and does not differentiate between perception and the perceived world, or, between his own activity and the movements of objects. This premise might be argued against by pointing out the existence of three sets of information, each providing sufficient basis for the distinction between movements of the self and movements of objects.

The first set of information are non-visual, kinesthetic signals which report on the movements executed by the self, and which are obviously absent when the perceived movement was made by an agent other than the self. Piaget discussed this objection in "The Child's Construction of Reality" (CR, p. 104), and rejected it by claiming that since the infant cannot distinguish internal from external as such, infant thought can attach any sort of body sensation to any perceived movement. Analysis of Piaget's answer reveals it to be begging the question: as long as it is not shown that the infant cannot in fact make use of available (sensory) information to make distinctions between internal and external agency of movement, it remains unproven that he cannot distinguish internal from external as such.

The second set of information is the presence or absence of volition. Apart from special circumstances, the self's movements are voluntary, active and self-initiated. This is a powerful marker which is absent from situations where the self is quiescent. It has even been claimed (Von Holst and Mittelstadt, 1950) that the will to move (rather than the execution of the movement) is the central factor in determining whether a given visual change will be perceived as movement of the self or of the external world.

The third set of information is purely visual. As Gibson (1950) has so convincingly pointed out, the visual effect of a movement of the self is usually completely different from the visual effect of a movement of an object. The movement of the self causes a complete transformation of the whole visual field, while the movement of an object only transforms that object plus a small part of its background.

To recapitulate, there exists visual, kinesthetic and control information which should enable the infant to distinguish with certainty between the different agents of visual change. In order to claim, as Piaget does in Hypothesis A, that the infant cannot or does not make use of these systems of information in order to distinguish between movements of self and movements of objects, it is necessary to prove directly that his perception is dif-

ferent or erroneous. As pointed out earlier, most of Piaget's evidence concerns search situations, namely observations on infant behavior in the *absence* of the (relevant) objects. There is no direct evidence to show that the infant's perception of visual change is qualitatively different from that of the adult. Hypothesis A is not proven.)

* * *

B. Hypothesis: The infant has no means of distinguishing the source of change in the shape of objects, namely, he cannot specify whether it has resulted from a change of state or from a change of position of the object (CS, p. 9, p. 103).

Evidence:

1. Observations on the behavior towards vanished objects or parts of objects;
2. Observations on the imitation of facial gestures;
3. Observations on shaking of head and body while looking at hanging objects;
4. Observations on the sucking of desired parts of objects.

Evidence 1–3: The first three sets of evidence were described in detail in connection with Hypothesis A.

Inference: (from the first three sets of evidence): The infant cannot distinguish between the movements of the object and the movements of his own body (Hypothesis A).

Inference: The infant confuses the act of finding a displaced image with the act of recreating it (CR, p. 103).

Inference: The infant cannot distinguish between changes of state and changes of position in the object (Hypothesis B proven).

(*Presupposition:* The elementary distinction between change of position and change of state of an object is that the former can be compensated by body movements which reinstitute the former perceptual state, while the latter cannot be compensated or annulled in this way. Therefore, the infant must be able to distinguish between compensable and non-compensable changes in the visual world in order that he be able to distinguish changes of position from changes of state in objects (CR, p. 102).)

(*Note:* Since Hypothesis A was not proven, it cannot be assumed as true and used to prove Hypothesis B. In consequence the first three sets of evidence are irrelevant to Hypothesis B.)

Fourth evidence: The infant, wishing to suck a specific part of an object, cannot turn the object immediately to the desired position, guided by vision, but has to grope around randomly with his mouth until he finds the desired place by chance (CR, obs. 67, p. 106–107; obs. 76, p. 123).

Generalization: The infant can adjust his mouth to the object but not the object to his mouth (CR, p. 108).

Interpretation: For the infant, space is the property of his mouth, not of objects (CR, p. 108). For him, there are no objects, only personal acts (CR, p. 35).

Inference: Since, for the infant, objects do not exist, it is impossible for him to distinguish between changes of state and changes of position in objects. (Hypothesis B proven.)

(*Note:* It might be possible to interpret the fourth evidence as showing merely that the infant can adjust his mouth but not his hands if he wishes to suck a specific part of an object he holds. This difference might have various reasons, such as better control over the movements of the lips than over the movements of the hands; or, the fact that the target is defined by the specific tactile sensations it arouses but not, yet, visually. Neither of these necessitates interpretation in terms of the non-existence of objects.)

* * *

C. Hypothesis: A change in the perspective of the object is perceived by the infant as an actual transformation of the object (CS, p. 11; CR, p. 168).

Evidence: Observations on the behavior towards rotated objects.

Observations: The adult rotates an object so that the infant is presented with an unfamiliar face of it. The infant does not turn the object so that its familar (or desired) part will face him unless he can see some of the familiar part. For example: he will not rotate a reversed feeding-bottle (presented with the bottom facing the infant) unless some part of the nipple is visible (CR, obs. 77, pp. 124–125; obs. 78 and 78a, pp. 126–128).

Interpretation: The infant considers the unseen part of the object to be "reabsorbed" into the object and to cease to exist spatially, rather than to be rotated and obscured by the visible parts of the object (CR, p. 130).

Inference: A change in the perspective of the object is perceived by the infant as an actual transformation of the object (Hypothesis C proven).

(*Note:* If hypothesis C is true, the infant should not recognize *any* perspective change of the object as a change of position. However, on Piaget's own evidence there are some changes of perspective which are recognized as such by the infant. I refer here to situations in which at least a small fraction of the familiar part of the object is visible, for example, of the nipple of a feeding-bottle. Since the familiar part (the nipple) seen from an unfamiliar angle (from the direction of the bottle's base) is a true example of a changed perspective of the object, it should not be recognized by the

infant. Nevertheless, the object *is* recognized and correctly rotated. It might be concluded that Hypothesis C is not true.)

* * *

D. Hypothesis: There is no shape constancy (CS, p. 11).

Evidence: Observations on the behavior towards rotated objects.

Observations: The adult rotates an object so that the infant is presented with an unfamiliar face of it. The infant does not turn the object so that its familiar (or desired) part will face him unless he can see some of the familiar part (CR, obs. 77, pp. 124–125; obs. 78 and 78a, pp. 126–128).

Interpretation: The infant considers the unseen part of the object to be "reabsorbed" into the object and to cease to exist spatially, rather than to be rotated and obscured by the visible parts of the object (CR, p. 130).

Inference: The infant cannot fit the momentary perception into an organized schema of rotary movements (CS, p. 216).

Inference: There is no shape constancy in the infant's perceptual world (Hypothesis D proven).

(*Presupposition:* Shape constancy is necessarily dependent on the existence of a schema for the organization rotary movements.)

(*Note:* It should be noted that Piaget does not refer in Hypothesis D to shape constancy as the process whereby the perceived shape of an object is constant in spite of a change in its perspective (e.g., Epstein and Park, 1963). Rather, Piaget refers to the knowledge that the object possesses a permanent three-dimensional form which remains unchanged through alterations in its perceived shape (CR, p. 148). Such knowledge might affect the perception of the object even if it *is* seen as different from different viewpoints.

That Piaget does not refer here to the constancy of perceived shape is clear from his examples, in which the test for shape constancy is not that the object would be perceived in any particular way, but that it would be *recognized* as the same object through changes in viewpoint (CS, p. 5). For example, a square which appears lozenge-shaped as a result of perspective should be recognized, through shape constancy, as a square, i.e., as a figure having equal angles and equal sides (CS, p. 11); a cube seen in perspective so that none of its sides appears as a square, should be recognized as a cube (CS, p. 15); a feeding bottle, seen from the direction of its bottom, should be recognized as the same object that contains a nipple (CR, pp. 128–130; p. 168); a toy duck, usually seen from the direction of its head and back, should be recognized if seen by its base (CR, p. 128). In some of these examples, perceptual shape constancy is actually impossible, since they

concern objectively different forms, such as the two opposite faces of a completely rotated object, e.g., the bottom and nipple of a feeding bottle.)

* * *

E. Hypothesis: There is no size constancy (CS, p. 5).

Evidence: An experiment by Egon Brunswik and Ruth M. Cruikshank, (Perceptual size-constancy in early infancy. *Psychological Bulletin,* 1937, *34,* 713–714).

Method: Infants of three to eight months of age were presented with three objects: *A*: a rattle presented at the distance of 25–30 cm; *B*: the same rattle as in A presented at a distance three times as great; *C*: an object of the same form and color pattern as the rattle in A and B, but three times as large, presented at the same distance as in B. (Method of presentation is not reported.) The reaching response of babies was studied. (Method of study and the definition of reaching response not reported.)

Results: (Responses at three months were not reported in the paper.) At around four to five months of age there was found some relatively slight degree of size-constancy, but on the average, situation C was not responded to with complete equivalence to situation A as would be the case if there were no constancy. (Mode of response not reported either for A, for B or for C.)

At about six months of age a differential response to situations A and C is developed, the response to C approaching the response typical for B.

Inference: There is no size constancy in early infancy (CR, p. 5). (Hypothesis E proven.)

(*Note:* Because of the lack of details in the Brunswik and Cruikshank paper it is impossible to infer the detailed presuppositional structure of this conclusion. Nevertheless it should be noted that the results of the experiment do not fully warrant the conclusion which was drawn from it, since at the youngest age group for which results were given, there is already a divergence of responses between the two critical situations. It might be concluded that Hypothesis E is not proven.)

* * *

F. Hypothesis: The infant perceives space at the first period of his life as a fluid mass without depth (CR, p. 145).

Evidence: Observations on the absence of systematic binocular convergence until 9 months of age (CR, obs. 68, p. 111).

(*Presupposition:* Systematic binocular convergence is a necessary condition for depth perception.)
(*Notes:* There are different and conflicting claims made by Piaget about depth perception, e.g., (CR, on p. 111) he says that the infant does perceive at various depths, but that he is not conscious of these depths. It is also possible that Piaget did not intend to offer the observations above as conclusive evidence for the absence of depth in early infancy. In that case Hypothesis F is without any proof.)

* * *

G. Hypothesis: At a later period in infancy, space becomes differentiated into two zones, "near space" and "far space" (CR, pp. 143–145).

Evidence:

1. Observations on the attempts to grasp near and far objects;
2. Observations on the approach to distant objects.

1st Evidence: Near objects are grasped while usually there is no attempt to grasp distant objects (CR, obs. 81–83, pp. 135–141).

2nd Evidence: Distant objects are approached in order to be grasped, sucked or seen better (CR, obs. 81 and 83, pp. 136, 139).

Interpretation: The infant differentiates between "near space" and "far space", the former of objects suitable for prehension, the latter of objects which are not suitable for it. (Hypothesis G proven.)
(*Note:* There is no evidence that infant space at this stage, or at any other, is differentiated into two discontinuous zones, rather than perceived as a continuous whole in three dimensions. The evidence offered for Hypothesis G is consistent with adult-like perception of distances. Therefore Hypothesis G is unproven.)

* * *

H. Hypothesis: The differentiation between "near space" and "far space" is not that of depth (CR, pp. 143–145).

Evidence: Observations on the search for hidden or covered objects.

Observations: The adult covers an object with a cloth or hides it behind a screen, in full view. The infant does not uncover it or search for it behind the screen (CR, obs. 7, p. 15, obs. 22–25, pp. 28–32; obs. 28–32, pp. 36–40).

Interpretation: The infant does not have the concepts of "in front of" and "behind" (CR, p. 111).

Inference: Visible objects are not perceived as arranged in sequential planes one behind the other, ordered according to the third dimension. (Hypothesis H proven.)

(*Presupposition 1:* Space in adults is perceived as a succession of two dimensional planes, ordered one behind the other according to the third dimension (CR, p. 171).)
(*Presupposition 2:* The infant must acquire the concepts of "in front of" and "behind" as applicable to hidden objects as a necessary condition in the perception of non-hidden objects arranged in three dimensions.)
(*Note:* There is an essential incongruity in using data collected exclusively in the absence of objects to infer on perceptual processes occurring in the presence of objects (= stimuli).)

* * *

I. Hypothesis: The objects in "far space" appear to the infant diminished and distorted by perspective (CR, p. 143).

Evidence: Observation on the attempts to grasp distant, and near, but unfamiliar, objects.

Observations: The infant does not attempt to grasp distant objects, nor near objects which are not very familiar or which are presented in abnormal circumstances (CR, obs. 83, p. 138–140).

Interpretation: The infant does not attempt to grasp distant objects since they appear to him distorted, unfamiliar, and linked to a context in which direct prehension has never intervened (CR, p. 143).

Inference: Distant objects appear to the infant distorted and diminished by perspective. (Hypothesis I proven.)
(*Note:* The similarity between the infant's behavior in two situations is not by itself a proof that the reason for that behavior is identical in both cases. It is still possible that the infant does not attempt to grasp distant objects not because they look unfamiliar but because they look distant. Therefore Hypothesis I is unproven.)

* * *

J. Hypothesis: "Far space" is undifferentiated into depth planes (CR, p. 145).

Evidence: None.

Proof 1: Differentiation into depth planes through prehension, which has just been attained for "near space", is obviously impossible for "far space", therefore "far space" remains undifferentiated into depth planes (CR, p. 146). (Hypothesis J proven.)
(*Presupposition:* Near space is differentiated into depth planes through the coordination of vision and prehension (CR, p. 145).)

(*Note:* Prehension cannot be a necessary condition for the differentiation of depth in "far space" since it is logically impossible ever to grasp distant objects. Since it is never a necessary condition, the lack of it in infancy does not imply that infants cannot differentiate depth in "far space". Hypothesis J unproven.)

Proof 2: The three necessary conditions for adult perception of distant depth are not yet realized. These are:

a. The greater number of objects interposed between object and observer, the more distant the object seems;
b. Objects interposed on each other are perceived in varying depth;
c. The different speeds of displacements observed by moving the head or the whole body enable the observer to evaluate the parallax of distant objects (CR, p. 147).

Therefore, "far space" is undifferentiated into depth planes (Hypothesis J proven).

Evidence: None.

(*Presupposition:* Depth perception in adults is necessarily based on the number of objects between observer and distant object, on interposition, and on movement parallax.)

(*Note:* Since no evidence is offered, Hypothesis J is unproven.)

* * *

K. Hypothesis: The infant does not perceive spatial relations of projective and euclidean (i.e., higher than topological) order (CS, p. 6).

Evidence:

1–2–3: The absence of shape constancy in the infant.

2–3–4: The absence of size constancy in the infant.

First Evidence: The absence of shape constancy in the infant has been discussed as Hypothesis D (pp. 21–22). The main evidence has been difficulties with completely rotated objects, e.g., a feeding bottle.

Inference: The infant is unable to coordinate the various perspective projections of an object (CS, p. 12).

(*Presupposition:* Coordination of perspective projections is a necessary and sufficient condition for shape constancy (CS, p. 12).

Inference: The infant does not perceive the *projective* relationship between different perspective projections of an object. (Hypothesis K proven.)

(*Presupposition:* There exist projective correspondences between perspective projections of an object.)

(*Note:* It should be noted that there is no projective correspondence (or relation) whatsoever between the opposite sides of a completely rotated object, e.g., between the bottom and the nipple of a feeding-bottle. It might be true that between any two perspectives in most objects there exist an infinite number of intermediate perspectives, each having *some* projective correspondence with its neighbors, so that these correspondences are capable, as Piaget claims (in CS, p. 12) of coordinating the different perspectives into an integrated whole. Furthermore, it might also be possible that the infant has difficulty in taking advantage of these correspondences in order to recall one perspective on the basis of seeing its opposite; or that he cannot make use of the network of coordinated perspectives in order to correctly rotate an object to a favored orientation. Nevertheless, Piaget does not offer any evidence that infants are unable to take note of and make use of a direct projective correspondence, if it exists. On the contrary, his evidence points to the opposite conclusion: whenever there is some possibility of finding a projective correspondence (namely in those situations when a small part of the "favored part", e.g., the nipple of a feeding-bottle, is showing), the infant acts in a positive way, e.g., rotates the bottle. It might be concluded that Hypothesis K is incorrect as a general unqualified description of the infant's perceptual limitations.)

Second Evidence: The absence of shape and size constancies in the infant have been discussed as Hypothesis D (pp. 21--22) and Hypothesis E (pp. 23–24).

Inference: The infant cannot recognize or reconstruct a fixed euclidean shape (CS, pp. 10–12).

(*Presupposition 1:* Shape constancy is the recognition or reconstruction of euclidean shapes, namely, of shapes possessing constant euclidean properties such as length, angle, etc. (CS, p. 11).)

Size constancy is the reconstruction of euclidean shapes, namely of shapes possessing constant size.

(*Presupposition 2:* The absence of shape and size constancies necessarily implies an inability to recognize or reconstruct the euclidean properties of an object.)

Inference: The infant does not perceive the euclidean properties of an object (Hypothesis K proven).

(*Presupposition:* Inability to recognize or reconstruct the euclidean properties of an object necessarily implies that such properties are not perceived in general.)

(*Note:* Piaget begs the question of topological primacy in the juxtaposition of recognized and non-recognized shapes. Whenever there is "recognition of

shape independent of perspective" in infancy, such as of faces, he identifies the basis of it as a topological, homeomorphic correspondence. However, of all the objects the infant cannot recognize at this age he discusses only a small subset, all of which are "euclidean", rigid objects with well-definable metric attributes, such as a feeding-bottle or a celluloid duck (CR, pp. 126–128). Even his non-empirical examples for shape constancy are of this character; a cube; a square, a rectangle (CS, pp. 11–15). It might be argued that faces have higher-order invariants serving for recognition, such as the triangle of the two eyes and the nose; and that furthermore Piaget's test for recognition is completely different for rotated objects on the one hand, and for faces, on the other hand; for example, the infant is never required to rotate a face or to manipulate it in any way in order to demonstrate recognition. For these reasons it might be concluded that Hypothesis K is unproven.)

Third Evidence: The absence of shape constancy in the infant has been discussed as Hypothesis D (pp. 21–22). The absence of size constancy in the infant has been discussed as Hypothesis E (pp. 23–24).

Inference: The infant is unable to abstract a straight line from the boundaries of a complete figure, as long as the figure is not yet assumed to indicate the presence of objects with fixed shapes and sizes (CS, p. 10).

(*Presupposition:* Abstracting straight lines from boundaries of figures is impossible if these figures are not assumed to indicate the presence of objects with fixed shape and size.)

Inference: The infant cannot perceive straight lines (CS, p. 10). (Lines are projective invariants, therefore Hypothesis K is proven.)

(*Presupposition:* Straight lines exist perceptually only if they are first abstracted from boundaries of figures (CS, p. 10).)

Fourth Evidence: The absence of size constancy in the infant has been discussed as Hypothesis E (pp. 23–24).

Inference: The infant is unable to coordinate the various perspective projections of an object which changes in size with varying perspective (= distance) (CS, p. 11).

(*Presupposition:* Coordination of perspective projections of various size is a necessary and sufficient condition for size constancy.)

Inference: The infant does not perceive the projective relationship between perspective projections of the object which vary in size as a function of distance (Hypothesis K proven).

(*Presupposition:* There exists a projective correspondence between perspective projections of the object which vary in size as a function of distance.)

(*Note:* The geometrical relations between receding "perspectives" of an object is that of similarity, which is not a projective but an affine relation. This in itself does not disprove Hypothesis K which refers generally to relations of higher than topological order.)

Discussion

Although the orientation of this paper has been mainly descriptive, two points of criticism have emerged which warrant further discussion. The first issue concerns Piaget's heavy use of the search paradigm in proving perceptual hypotheses, e.g., on the perception of the agency of visual change; on shape constancy; on the perception of depth. Piaget prefers this paradigm on the grounds that the child's search behavior reflects the understanding, consciousness and structuring of sensation, rather than the sensory activity itself (CR, pp. 134–5, pp. 213–214).

One could easily accept Piaget's argument that perception involves more than mere sensation, and still insist that sensory activity is abolutely necessary for perception to occur. On this ground, observing the infant's behavior in the absence of stimulation is not an appropriate way to arrive at valid conclusions about the nature of perceptual processes, although there might be other processes which this paradigm elucidates, namely representation in memory, search strategies, probability learning, etc. It might be possible to claim that these latter processes are perfectly identical to the "intelligent" component of perception, and it is even possible that this represents Piaget's point of view, but this sort of argument cannot be accepted without strong proof, which is absent from the Piagetian corpus.

The second issue is formal, and concerns Piaget's widespread reliance on unproven claims about the nature of perception. For instance, he assumes that imitation of facial gestures depends on visual knowledge of one's face; that near space is differentiated into depth planes through the coordination of vision and prehension; that straight lines are perceived only if they are abstracted from the boundaries of objects, given that these are attributed with constant size and shape, and so forth. Since the falsity of a presupposition falsifies the premise that depends on it, the analysis of presuppositions should take an integral part in any critical examination of Piaget's theory.

References

Barlow, H. B., Blakemore, C., & Pettigrew, J. D. (1967) The neural mechanisms of binocular depth discrimination. *J. Physiol., 193,* 327–342.

Bower, T. G. R. (1968) Morphogenetic problems in space perception. In: D. Hamburg & K. Pribram (Eds.), *Proc. Assoc. for Research in Nervous and Mental Diseases.* Stanford, California, Stanford University Press.
Brunswick, E., & Cruickshank, R. M. (1937) Perceptual size-constancy in early infancy. *Psychol. Bull., 34,* 713–714.
Epstein, W., & Park, J. N. (1963) Shape constancy: Functional relationships and theoretical formulations. *Psychol. Bull., 60,* 265–288.
Flavell, J. H. (1963) *The developmental psychology of Jean Piaget.* Princeton, Van Nostrand.
Gibson, J. J. (1950) *The Perception of the Visual World.* Boston, Houghton-Mifflin.
Ginsburg, H., & Opper, S. (1969) *Piaget's Theory of Intellectual Development.* Englewood Cliffs, Prentice-Hall.
Holst, E. von, & Mittelstädt, H. (1950) Das Reafferenz-prinzip. *Naturwissenschaften, 20,* 464–476.
Hubel, D. H., & Wiesel, T. N. (1962) Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *J. Physiol., 160,* 106–154.
Hunt, J. McV. (1961) *Intelligence and Experience.* New York, Ronald.
Maturana, J. R., Lettvin, J. Y., McCulloch, W. S., & Pitts, W. B. (1960) Anatomy and physiology of vision in the frog. *J. Gen. Physiol., 43,* Supplement, 129–171.
Pettigrew, J. D., Nikara, T., & Bishop, P. O. (1968) Binocular interaction on single units in cat striate cortex: Simultaneous stimulation by simple moving slit with receptive fields in correspondence. *Exper. Brain Res., 6,* 391–410.
Piaget, J. (1951) *Play, Dreams and Imitation in Childhood.* New York, Norton.
Piaget, J. (1952) *The Origins of Intelligence in Children.* New York, International Universities.
Piaget, J. (1955) *The Child's Construction of Reality.* London: Routledge and Kegan Paul.
Piaget, J., & Inhelder, B. (1956) *The Child's Conception of Space.* London: Routledge and Kegan Paul.
Wolff, P. (1960) The developmental psychologies of Jean Piaget and psychoanalysis. *Psychological Issues,* Monograph No. 5, New York, International Universities.

Résumé

On présente la théorie de Piaget sur la perception de l'espace par les jeunes bébés dans le cadre d'un système hypothético-déductif. Les auteurs définissent 11 hypothèses portant sur: l'agent du changement visuel, des constances de forme et de taille, de la distance et de la perception des relations d'un ordre supérieur entre les éléments spaciaux. Les propositions de Piaget pour chacune de ces hypothèses sont présentées en plusieurs étapes: la preuve comportementale, l'interprétation en terme d'états intérieurs, les inférences et généralisations. Les présuppositions qui sous-tendent les arguments sont mis en évidence et des notes critiques sont insérées aux moments appropriés. Enfin, les conclusions générales sont brièvement discutées.