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ABSTRACT

This theoretical paper reevaluates the Piagetian tradition in the study of propositional reasoning. Piaget's assertion that children's logic, prior to the stage of formal operations, is structurally adequate for dealing with objects and their properties, but is inadequate for fully competent propositional reasoning, is challenged on three grounds: (1) the data base from which Piaget's theory about formal reasoning has been developed comes from a scientific task domain with its specific task requirement and associated psychological factors; (2) the theory cannot, a priori, be extended to other propositional task domains, and empirical support for generalizing it has not been provided; (3) findings from adult studies show that adults tend to rely on empiric (rather than propositional) reason whenever it is possible to do so. Therefore, there are interesting similarities between child and adult reasoning which the Piagetian outlook has de-emphasized. A linguistically oriented view on the development of propositional reasoning is proposed, based on the idea that acquiring propositional competence is an achievement of the same nature as acquiring competence in grammar or syntax. The theoretical and methodological consequences of this view are examined. (GO)

The Development of Propositional Reasoning: Conceptual Issues, and Suggestion of a Perspective for Empirical Research [1]

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The aim of this paper is to compare two approaches to propositional reasoning, one of which is the Piagetian approach; to examine the connections and distinctions between these two approaches; to examine the relevance of Piaget's theory to propositional reasoning in general, to propose a somewhat different view, though by no means contradictory in my opinion, namely a linguistic perspective on what propositional reasoning involves; and to indicate how this view suggests plausible mechanisms and research questions concerning the development of propositional reasoning.

There are two traditions in the study of propositional reasoning. One is the Piagetian tradition. The other focuses on how people reason about verbally stated, self-contained problems such as syllogisms. The latter tradition has mostly focused on adult reasoning and I would like here to defend the view that this state of affairs stems from a prejudice unsupported at this point. This prejudice concerning children's inability to handle verbal logical problems such as syllogisms or other forms of propositional inference, is founded on Piaget's assertion that children's logic, prior to the stage of formal operations, is structurally adequate for dealing with objects and their properties but is inadequate for fully competent propositional reasoning. The claim made here that this prejudice is unsupported, at least in the radical form in which it is often expressed, is based on the following three considerations that I am going to briefly outline and then develop somewhat.

The first one is that the data base from which Piaget's theory has been developed comes from an empirical task domain different from the "propositional" situations mentioned above, and therefore cannot a priori be generalized to these situations. I will try to differentially charocterize these two respective task domains in a moment. The second point is that, whether such a generalization is valid can only be answered on empirical grounds, that are as yet lacking, precisely because of the scarcity of empirical developmental work in the "propositional" areo. Thirdly, the fact that adult reasoning in propositional situations is notoriously only in loose correspondence with what the ideal logical model would prescribe, should lead us to reconsider what is meant by saying thot the individuol, from adolescence on, is in the stage of formal operations in contrast to his previous inadequacies in that respect. Whot I am referring to, of course, are the problems facing the validation of a competence model when its actualization at the behaviorol level is imperfect; but also and much more crucially, in the context of the present argument, the difficulty of denying such competence to other individuals whose inadequacy in performance only differs from the former by a matter of degree.

(a) Difference in the tosk domains investigated

Aside from superficial differences between the Piagetion ond "propositional" tosk domains, a fundamental difference is thot, while "propositional" studies focus on the child or the adult as a logicion, the Piogetion approach focuses on the child as a scientist. These are two distinct endeavors, psychologically. (We may ignore for the present purpose the epistemological status of logic, namely the fact that it is structurally constrained to only generote empirically valid conclusions from empirically valid premises). Studying the child as a logician is essentially a psycholinguistic enterprise in which the child's knowledge of language-as-an-object is focused upon; this

approach is a direct descendent of the conception of logic as a formalization of natural language, factual components are kept minimal in the input of the reasoning task, and the "appropriate" behavior is for the subject to disregard this incidental information and draw conclusions from the premises in much the same manner as a linguist would judge the grammaticality of a sentence. (Of course, because of what logic is, those judgments will ultimately be factually true if the premises are factually true, but this need not concern us here). In contrast in the Piagetian tradition, the child is studied in his/her scientist's attempts to discover properties of the real world, and typically tested in situations in which he/she has to draw inferences about a natural phenomenon (as in the physics experiment described by Piaget and Inhelder, 1958). The "object of the game" is therefore different, in the same way as an empirical science differs from a formal discipline in what it aims to achieve. Piagetian studies purport to study children's logic, and they do indeed, to the extent that logic mediates scientific inquiry. But they also intrinsically involve other functions or task requirements as does scientific inquiry. One of those requirements, crucial for the contrast being made here, is that the child has to generate a preliminary description or encoding of the real events themselves, that is, of the empirical premises to which logic will then be applied. This is an essential part of what the child has to do when engaged in such situations, and a relevant description of real events is a prerequisite for appropriate inferences to be possible. A particularly obvious example illustrating this point is found in Inhelder and Piaget billiard table experiment, in which a ball is propelled through a tube of adjustable direction with adjustable strength, and the child has to discover, through manipulation of the device, that the angle of reflection of the ball on the edge of the table equals the angle of incidence. Protocols of interviews of younger subjects reveal

that, when asked to describe the outcome of a trial, they often mimick the trajectory of the ball as being a curve rather than two straight segments. It is clear that such an encoding, from which the crucial information--the angle--is missing, precludes the appropriate inference and, prior to this, the appropriate experimental manipulation.

Evidently, then, inferential attempts in those scientific situations involve an inseparable compound of logic and encoded factual information. In contrast, in the "propositional" situation in which the child is studied as a logician, the information is given to him in propositional form and he is asked to exclusively rely on that information. Clearly propositional situations allow for modes of reasoning other than propositional, involving such resources as imagery, factual biases or others, as has been abundantly documented in the literature. Also, propositional information must clearly be encoded in some form in order to be processed, with all the resulting uncertainties, but the important point here is that the task can be solved by exclusively using the propositional apparatus (language comprehension, logic, and mapping between the two) contrary to the "scientific" tasks, which involve a subject-generated description of the factual state of affairs.

Strategy factors: hypothetics-deductive approach

So far, the differences that I have stressed between the two task domains concerned the task requirements and the components in the reasoning process associated with those. Another point is worth mentioning, namely the contribution of strategy factors (or, more generally, heuristic factors) to the reasoning process. Namely, a child may have the ability to reason propositionally, but fail to resort to it in certain contexts, for reasons related to biases, approach to the problem, or overload from other task requirements for example. This is not a blanket remark, and to see it more clearly, let me

step back for a moment and consider the various aspects to the notion of formal operations. The notion of formal operations has several facets that are, in part, logically independent.

(i) It provides a structural description of the adolescent's competence and, symmetrically, the structural limitations to the degree of complexity or type of operation that the pre-adolescent child is able to conduct.

(ii) It describes heuristic characteristics of adolescent thought, namely, the hypothetics-deductive approach to understanding of and theorizing about reality; and the combinatorial (experimental) approach to hypothesis-testing.

(iii) It describes characteristics of the reasoning process namely the ability to reason at a propositional level (that is to say, among other things, the ability to perform deduction by relying on formal rather than referential properties of the statements.)

This last aspect is the one that concerns us here. In the Piagetian situations, the subject can use propositional reasoning either in his encoding of experimental outcomes or in his generation of hypotheses. The point being made here is that the child may fail to resort to propositional reasoning in Piagetian situations not because of a "process deficiency" (defined as in (iii)), but because of his orientation at the heuristic level described in (ii). In other words, when the child is presented with explicit propositional material, he may well be able to deal with it propositionally (in some cases) although he would not tend to treat (or theorize about) factual information in that manner when reasoning about an empirical phenomenon.

(b) Extension of the theory

If the previous point is accepted, namely the notion that Piaget's theory about formal reasoning has been generated from a "scientific" task domain, with its specific task requirement and associated psychological factors; then the second point is obvious, namely, the notion that the theory cannot, a priori, be extended to the other task domain and that whether it is generalizable or not, is an empirical question.

For exactly that reason, the remarks made so far are not polemical, in the sense that they do not question the validity of Piaget's inferences within the task domain from which they were derived; rother, they propose that the study of children's reasoning in "propositional" situations need not be conceptualized as a test of, or a challenge to Piagetian theory.

(c) Adult reasoning versus children's reasoning

As defended above, propositional competence is defined by (at least) two properties: a structural property and an ability to deal with language at a formal level, i.e. to engage in a reasoning process based on formal properties rather than referential content of statements. Children are said not to possess the full apparatus of propositional calculus because of structural limitations; and to be unable to reason propositionally in the second sense. It is interesting, in counterpoint, to survey the adult literature in this regard.

While the first limitation of children's logic is a plausible one, the adult literature on reasoning (with syllogistic or propositional inference, e.g.) also contains numerous indications of faulty, non-standard, and sometimes systematically erroneous reasoning patterns (that can be blamed on the performance or competence part of the process, depending on one's ideology). This is so well known that it is not worth developing here, but it serves as a healthy reminder that adult's reasoning is not ostensibly logical and that complex issues arise in the assessment of competence.

The second point, concerning the ability to deal with language at a formal level, is less devious and more interesting. A wide range of results in the adult literature point at the fact that adult reasoning largely incorporates factual information about the situation at hand rather thon being based on the formal properties of the premises alone, as

should be the case if it were genuinely propositional. For example, in the context of class syllogisms, Revlis has shown that the reasoning process incorporates information stored in long term memory about the situation being mentioned, i.e. when the statements are meaningful, reasoning is, in part, factually based. Results pointing in the same direction have been presented by Staudenmeyer who showed very convincingly that in propositional inferences involving "if-then" connectives, the connective does not have a fixed standard meaning but rather functions as a place-holder, and the meaning and logical properties of the compound statements are governed by the pragmatic or factual content of the constituent statements. Similarly, Scribner for example has found that both children and adults exhibit an empiric bias whereby the subjects tend to rely on the factual information contained in the premises rather than on their formal characteristics to reach the conclusion.

These findings are extremely interesting in the present context, because they show that adults tend to rely on empiric reasoning whenever it is possible to do so. We may then put this finding in parallel with Inhelder and Piaget's findings indicating that children typically fail to reason propositionally when they are presented empirical information exclusively in the context of a "scientific" situation, and have to generate for themselves the propositions on which reasoning will then be applied.

Note that the "empiric" attitude observed in adults in propositional situations is readily seen as a bias rather than a symptom of logical incompetence. This might lead us to reconsider our perspective on the analogous phenomenon in children.

The discussion so far has emphasized the differences in task domain and perhaps psychological processes, between the Piagetian approach to logic and the work in the "propositional" area; has argued that whether Piaget's inferences about children's

logic can be extended to the latter task domain is an open question so far, for which the relevant empirical data are lacking; and that there are interesting similarities (in terms of biases, errors, style) between children and adult reasoning, which the Piagetian outlook has led us to de-emphasize. I would like now to propose a linguistically oriented view on the development of propositional reasoning and to indicate some theoretical and methodological consequences that follow naturally from such a view.

Development of propositional reasoning: a linguistic perspective

The following discussion will be concerned with children's reasoning in "propositional" situations, that is to say, in situations in which the information (premises) is stated verbally, in contrast to "scientific" situations. I will argue that logical development in that context can be described or theorized about, in exactly the same way as we characterize the development of syntax in the child. Before turning to this developmental issue, let us first acknowledge or remember that logic and syntax, as abstract systems, have a similar status with respect to natural language. Although the details of the parallel and the resulting issues are beyond the scope of this paper [2], it is enough to note that the two systems are alternative formalizations of natural language into, respectively, grammatical classes and rewrite and transformational rules; and propositions, connectives and schemes of inference. In fact, a scheme of inference can be conceptualized as a particular transformational rule generating a new, equivalent statement from another (or two or more) statement (s), on formal grounds.

If one recognizes this parallel, it is then natural to propose that the processes governing the acquisition of logical and syntactical competence may be similar; and to look at both syntactical and logical development as a process of gradual structuring of the linguistic environment. In the same manner as the child learns to structure

his/her linguistic environment by identifying grammatical classes, function words, and legitimate ways to articulate these, he/she may be assumed to structure the linguistic environment in terms of what statements can be legitimotely derived from what other statements under whot conditions.

One may view this gradual acquisition of grammatical or logical competence os o concept learning process, where the concepts learned are structural concepts (the structure of a given rule of inference, such as modus ponens; or the transformational rule generoting questions from declorative statements of a given type).

In acquiring these concepts, formal cues as well as referential cues have to be used. For example, nouns usually designate objects (at least in the early stages of language acquisition) whereas verbs typically designate actions or changes. The child can therefore use referential cues to form the grammatical categories on which grammar and syntax will then be based. Similarly, both referential and formal ingredients are involved (potentially) in the child's acquisition of a logical rule: the child moy learn valid potterns of inferences either referentially, by observing which potterns leod to valid conclusions; or by using the adult's feedbock on the correctness of his/her discourse. In either case, learning a given pattern of inference involves picking up the essential functicn words ond other relevant cues, and abstracting the structure of the argument. At a given age, the child may be able to reason propositionally for those inferences thot are sufficiently simple or familiar. For example, a five-year old may know thot if o statement A is true then its negation is false whotever A means; and apply this knowledge without going back to the referential meaning of A. This is indeed a case of propositionol reasoning. For other, more complex inferences, partly valid, partly empiric reasoning may be used, until the structural concept has been

formed at a sufficiently general level (the specifics of this acquisition process clearly need elaboration, but this could only be speculation at this point, in the absence of a sufficient body of empirical data). Let us note in passing here that, even when the propositional concept is formed, the child may resort to empiric reasoning in some cases, as the adult does. Assuming that the child's propositional competence includes a given logical rule, does not imply that the child reasons at a propositional level in all the corresponding cases, but only that he possesses that knowledge at an appropriately abstract level. This is the familiar situation related to the use of a competence model, and now familiar in linguistics.

To briefly recapture the argument developed here, what I am proposing is the notion that acquiring propositional competence is an achievement of the same nature as acquiring competence in grammer and syntax; and that the high level of sophistication reached by young children in the latter domain lends credibility to the view defended here about the development of propositional reasoning.

This view has obvious methodological implications. Techniques that have proven fruitful in the language development area, are of obvious relevance to the study of propositional reasoning: analysis of longitudinal samples of discourse aimed at identifying patterns of propositional reasoning and their emergence; imitation techniques; judgments by the child about the appropriateness or logicality of a statement, aimed at assessing his/her logical competence with the minimal intervention of performance factors; selective intervention or training techniques aimed at mimicking the environmental factors presumed to be relevant to logical development. This is a promising and almost totally unexplored research area.

In conclusion and in the context of this symposium, it is important to note again that assuming a developing propositional competence in the child is not incompatible per se with the notion that pre-adolescence marks the access to the stage of formal operations. As argued before, the notion of formal operations is primarily a structural notion ascribing structural limitations to the complexity or type of operations a child is able to perform. Such a limit placed on the system of operation is logically independent from any assumptions one might make concerning the ability to reason at a propositional level. Propositional reasoning may develop in the young child, yet remain structurally incomplete until adolescence, and, as argued before the young child's inability to deal propositionally in scientific situation does not prejudge of his/her capacity to do so otherwise.

Footnotes

1. Much of this paper is based on the Introduction (Chapter 1) and Overview (Chapter 10) of R. J. Falmagne (Ed.), Reasoning: Representation and Process. Hillsdale, N.J., Lawrence Erlbaum Associates (in press, August 1975).

2. In particular both systems have the same status with respect to semantics, and the issues raised in linguistics concerning Chomsky's approach to syntax, can be transposed to logic as a formalization of language. Also, the definitional issues related to the notion of competence are similar in both cases. See Footnote [1]