The Semantics of Children's Language

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Interest in language, especially that of children, has become a central concern of contemporary psychology. This interest is somewhat surprising, because everyone recognizes the enormous complexity of language use and language development in the child. In spite of a widespread recognition that there is little hope of having a complete theory of these matters at any time in the near future, a general air of activity and in some cases of optimism prevails about the progress being made. For example, it is now possible to cite a fairly large number of references in the literature on almost any aspect of language development in the child, ranging from phonology to semantic comprehension, with probably the largest number of studies being on the syntactical or grammatical development of children's language. It is surely in this area that the most progress has been made over the past decade or decade and a half.

I have been involved in several such grammatical studies myself (Suppes, 1970; Suppes, Smith, & Léveillé, 1972), and I believe in the intrinsic merit of the diversified work that is going on all over the world. On the other hand, I do feel that too great an emphasis has been placed on grammar or syntax, and too little on semantics. I want to try to help redress the balance by making the case for an intensive study of the semantics of children's speech. I shall be especially concerned to argue that there are as many conceptual and technical tools available for semantical analysis as there are for syntactical analysis, but as yet these tools are less familiar to psycholinguists and to psychologists in general than is the concept of a generative grammar. Moreover, psychologists have developed a habit of listening to the latest word from linguists on syntactical matters, and to some extent this has transferred to semantics. Part of my thesis is that while linguists have had little of interest to say about semantics, there is a deep and conceptually rich tradition in logic and philosophy that can be used for the semantical analysis of children's speech and that can provide a body of methods and concepts appropriate to the task. It is not my objective to be controversial and dialectical in this lecture, but I want to emphasize from the beginning my conviction that when it comes to semantical matters, the tradition of model-theoretic semantics that originated with Frege (1879) in the nineteenth century is the serious intellectual tradition of semantical analysis, and the recent offshoots by linguists, to a large extent conceived in ignorance of this long tradition, have little to offer in comparison.

Logical Tradition

The tradition I identify as beginning with Fregealthough it has an informal history that runs back at least to Aristotle—is concerned with providing a precise and explicit analysis of the meaning of an utterance. This is not the place to give a history of these developments, but I do want to sketch the central concepts that are particularly relevant to the analysis of children's language. It came to be recognized fairly early that one way to analyze the meaning of an utterance is to state under what conditions the utterance is satisfied. In the case of declarative sentences, this amounts to giving truth conditions; in the case of questions, conditions on a correct answer; and in the case of commands, conditions on a response that satisfies the command.

Perhaps the most important step after Frege was the explicit analysis of the concept of truth by Tarski (1935) in his celebrated monograph. Tar-

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Figure 1. Semantic tree for the English noun phrase *black cats*.

ski's analysis of the concept of truth is restricted to formal languages, and much of the development of semantics in logic and philosophy since the 1930s has been concerned with formal languages. No doubt the preponderance of emphasis on formal languages has put off deeper perusal of these matters by psycholinguists who might otherwise be attracted to the theoretical developments. What has come to be called the theory of models in logic, which is really the semantical theory of formal languages, has been relatively inaccessible to outsiders until fairly recently.

As I have already indicated, it is my contention that the concepts developed in this logical tradition are of central relevance to the semantics of children's language. I want to sketch why I think this is so, but also to emphasize that I do not claim that all the intellectual problems that must be faced in giving an adequate theory of the semantics of children's language can be solved by any simple and direct application of the concepts taken from the logical theory of models. I shall have more to say about this later.

The basic semantical notion is that of a sentence or a collection of sentences being satisfied in a model. The intuitive idea of such satisfaction is close to the intuitive concept of truth.

Thus, when Nina (one of the children I shall be quoting extensively in this article) says "Bring me some more candy canes," the semantics of satisfaction of that command is, it seems to me, as straightforward as satisfaction of the simple mathematical command "Add 5 and 7." We all have a clear intuitive understanding in both cases of what satisfaction of the command is and what the appropriate state of affairs would be in which either command would make sense with its satisfaction being describable in relatively simple terms.

To make these intuitions explicit is much easier in the case of elementary formal languages. Their syntax is restricted to sentential connectives, predicates, variables, the universal and existential quantifiers, and parentheses for punctuation. A model for a sentence of such an elementary formal language consists just of a nonempty domain, a subset of that domain for each one-place predicate, a binary relation for each two-place predicate, and so forth. A simple, but explicit, formal definition of what it means for a sentence to be satisfied in such a model is then easy to give.

Once a concept of a model is introduced for an elementary formal language, the most important semantical relation between sentences, that of logical consequence, is easily defined. One sentence of the language is a logical consequence of a second just when the first sentence is satisfied in any model in which the second is satisfied.

Direct application of these ideas to a child's language encounters at least three sorts of difficulties. First, the syntax of the child's language is more complicated than that of elementary formal languages, even in the case of a child between the age of two and three years. Second, the idea of considering any model of a child's utterance seems on occasion too broad and leads to a notion of consequence that seems too general. Third, the sentences of an elementary formal language are selfcontained in their meaning relative to a model that can be easily described. In the case of much of a child's speech there is a vagueness of context and at the same time an apparent high dependency on context that is not easily dealt with by any explicit notion of model. I want to say something about each of these difficulties in turn.

Semantics of Context-Free Grammars

The approach to the first problem of syntax is to restrict initial analysis to that part of the child's language for which a context-free grammar can be written. The semantics of such context-free languages or context-free fragments then consists essentially of two parts. The first part is the assignment of a denotation to individual words or phrases occurring in the child's speech. In many instances, this assignment of denotation would of course vary from one context of use to another, but this variation merely corresponds to using different models on different occasions. Thus, when Nina says "Get big ball," we assign the denotation of a certain two-place relation to get, we assign the set of balls in the immediate environment as the denotation of the word ball, and we assign a denotation to the adjective big that is not simply the set of big things in the environment, but something more complicated that I shall discuss later in a more detailed consideration of adjectives.

The second part of the semantics is to provide rules for putting the individual denotations together in a way that fits hand and glove with the syntactic structure of the utterance by assigning a semantic function for combining denotations to each production rule of the grammar. This may sound somewhat abstract and complex, but the intuitive idea is simple, as may be illustrated in some examples drawn from a second corpus, a group of sixyear-old black children talking to each other (these children were born and live in Southern California). One of the children said "Black cats could climb up a ladder." Let us look at the subject noun phrase black cats. Our grammar for noun phrases contains the production rule $NP \rightarrow Adj + N$. As shown in the tree in Figure 1, the semantic rule attached to the grammatical rule is simply that of intersection for this simple noun phrase. On the left-hand side of each node we show either a terminal word or a grammatical category, and to the right of the colon in each node, the denotation of that node. Thus, in the present case the denotation



Figure 2. Semantic tree for the French noun phrase crayon rouge.



Figure 3. Semantic tree for the Mandarin noun phrase *hong2 mao2 yi1*.

of *black* is the set B of black things, and the denotation of *cats* is the set C of cats. Using the semantic rule of intersection, we see that the denotation of NP as shown in the tree is simply $B \bigcap C$.

A French sample of a similar sort, taken from the corpus of Philippe, a young Parisian child, indicates that the semantic tree for a noun phrase looks very similar, even when the adjective follows the noun, due to the fact that intersection of sets is commutative (see Figure 2). In the simple case under consideration, similar semantic trees can be found in languages quite different from English. Here is an example drawn from the spoken speech of Lingling, a two-year-old child whose language is Mandarin and who lives in Taiwan. The semantic tree for *hong2 mao2yi1* (red sweater) is shown in Figure $3.^2$

The three examples I have given are exceedingly simple. It is no triumph for any theory to be able to give an analysis of them. On the other hand, it is not appropriate here to undertake a full-scale systematic analysis of the speech of any of the children referred to. Extensive technical reports already exist for several of the corpora, and some of the analysis is so detailed and massive that I wonder if the reports will have any readers besides the authors themselves (Smith, 1972; Suppes, 1971; Suppes & Gammon, 1973; Suppes, Smith, & Léveillé, 1972).

² Examples drawn from the Lingling corpus are written in pinjin notation for Mandarin with tones indicated by the numerals 1-4 to make possible linear processing of computer input and output.

To provide illustrations that I think are suggestive of the direction taken by the full-scale analysis, I would like to consider four topics: the definite article, adjectives, quantifiers, and the expression of propositional attitudes in children's speech.

THE DEFINITE ARTICLE

In English the definite article is not used at the very beginning of connected speech by young children, but it does appear early. In the case of Nina, shortly after she was two years old frequent uses are found: the little boat, the little baby, I want the next page, I don't want the finger, I want the lion.

The use of the definite article is even more common in spoken French at the age of two or shortly thereafter. Here are some of Philippe's examples: pas chercher les voitures, dans la main, tombé le nours, la voiture, va chercher l'avion, tombé sur la bête, de l'eau, plein sur la cuisse, mangé le yaourt, le train, le métro, la valise, les chaussons là, chercher les livres, faire de la musique sur le nôtre.

Because there is no exact equivalent of the definite article in spoken Mandarin, I shall only consider the semantics of English and French. This does not mean that there is no way of giving definite descriptions in Chinese; rather, it means that different semantical and syntactical methods are used.

There is a familiar story in logic and philosophy about the analysis of definite descriptions and the introduction into formal logic of an explicit notation for the definite description operator. One of the classics of twentieth-century philosophy is Bertrand Russell's (1905) famous article on definite descriptions in which he shows how such descriptions can be eliminated in favor of more primitive His classic example is "The logical concepts. present king of France is bald." For analyzing children's speech or the informal talk of adults, the kind of analysis provided by Russell and the subsequent logical literature on definite descriptions does not seem to provide exactly the right approach, because the objective of the kind of analysis that deals directly with the spoken language is, as I have indicated, to provide a semantics that fits hand and glove with the syntax.

For this purpose, I have found that in many cases, but perhaps not all, it is useful to let the definite article *the* in English (and usually the corresponding definite article in French, for example) denote a set C that is the union of the set of ob-

jects in the perceptual surround with the set of objects denoted by phrases in immediately preceding sentences in the conversation, and in some cases, also the set of objects denoted by images or symbolic storage in long-term memory. Thus, when Nina said, "I want the lion," the set C denoted by the is intersected with the set of lions both real and toy, and if everything is in good order, the set intersection consists of a unique object. The set C as I have described it might in some cases be too large and thus the intersection would be too large. One device by which we can narrow the set C is to use a sequence of sets C_i with each element of the sequence being contained in the preceding member. The C that is appropriate in a given case is the first one that leads to a unique object when intersected with the set denoted by the remainder of the noun phrase. Without entering into technical details, I do want to remark that in the case of the definite article the correct semantic function for the production rule is not simply intersection, but intersection only in the case when everything is normal. When it is not, some Fregean or Russellian device is used. Obviously, also, the analysis must change when the definite article is used with a plural noun phrase, as when Nina says "I want the big boxes." In this case, the semantic function places a different cardinality requirement. Rather than a unique object in the intersection there must be at least two objects for the normal meaning to go through.

Whether the explicit decision is taken to let the definite description denote when the proper number of objects is not found in the intersection is really a technical decision and not an important conceptual one. One alternative is to treat the phrase as meaningless and nondenoting, and another is to introduce some arbitrary abstract object as Frege suggested. What is interesting is that the decision here is about as arbitrary and conventional as it is in the case of highly formalized languages, for example, as in a formalized language for axiomatic set theory.

To give you a crude idea of how the set C works, in the analysis of the spoken language of the Southern California black children I mentioned earlier, Elizabeth Gammon and I looked at the 4,300 noun phrases in the corpus (Suppes & Gammon, 1973). It was our approximate judgment after we examined the 265 uses of the definite article that in 126 cases the set C could be restricted to the perceptual surround. In 99 cases the set C could be restricted to objects denoted in immediately preceding sentences, and in 28 cases familiar objects like the moon, whose image or symbolic description was stored in long-term memory, seemed appropriate. In 12 cases the object referred to seemed to be in the mind of the speaker alone, and there was no easy extraction of the appropriate set C.

To give a sense of the frequency of occurrence of the definite article in the case of Nina, her speech recorded periodically from the age of 23 months to 39 months, with a corpus consisting of 102,230 tokens, contains 4,144 occurrences of *the*. Thus, a requirement of any systematic semantics of Nina's speech is to provide an analysis of the definite article.

In the case of Philippe's spoken French, running from the age of 25 months to 39 months, there are 56,982 tokens: *le* occurs 1,641 times; *la*, 1,457; *l*, 619; and *les*, 777 times.

Of course, the semantics of the demonstrative adjectives is very close to the semantics of the definite article. I shall not consider the ways in which we think they should be given a somewhat different semantics from that of the definite article to indicate continuing focus (*this* in English) or change of focus (*that*). In the case of Nina, there are 2,075 occurrences of *that*, 1,497 occurrences of *this*, 246 occurrences of *these*, and 341 occurrences of *those*.

SEMANTICS OF ADJECTIVES

I turn now to some semantic subtleties involved in the use of adjectives. Native speakers of English will say almost without exception big red book, little blue box, and so forth, but not red big box or blue little box. There is a good semantic explanation of this fixed order, and the order is found almost without error in young children's speech from the very beginning of the production of phrases that use an adjective of size as well as an adjective of color or some other adjective of simple classification. In the case of Nina, there are 370 occurrences of big and 674 occurrences of little. Here are all the instances in which either big or little is combined with an adjective of classification (there are other instances of intensifiers, for example, great big, that I shall not examine): big black; and a big white one; and there a big white one; big black seal; big dirty in her big mouth; big tiny mousie; yeah my big blue dog; I want the little tiny baby; little tiny stones; the little tiny one; and my little soft monkey; I got this pink little blanket (the only case of reversal of the fixed order mentioned above); I want my little white

blanket; little green table; Mrs. Wood's little green chair; that's yellow little yellow house; where's the little tiny one?; where's the more little green chairs?; where's the little green chair jall down?; yup, that's my little washing machine like you have a washing machine downstairs.

In the case of standard spoken French, the proper order is the adjective of size preceding the noun, which is followed by the adjective of classification. Here are a few samples from Philippe's speech: cherchez deux petites cabines bleues; où il est le petit filet jaune?; une petite vitre carrée; une petite fenêtre ronde; après il a mangé le petit chaperon rouge; et un petit nez noir; le petit bitonniau blanc; les petits bouts ronds là; le petit bitonniau blanc où il est?; la voiture elle fait tomber la petite machine verte; c'est quoi ces petits bouts ronds?; c'est quoi ces petits bouts ronds là?; tu vois les petits points jaunes?; tu veux un petit raisin séqué? (pour sec); mais je prépare des petites cabines bleues.

In the case of Lingling's Mandarin, the word order is similar to that of English; that is, the adjective of size or of some other characteristic of variable intensity precedes the simple adjective of classification. Again, as in the case of Philippe, I have not attempted to present a full listing, but only to give some samples: xiao3 zhen1 wang2zio (small real prince), xiao3 zhen1 lao3shu3 (small real rat), xiao3 ai3 ren2 (small short man), xiao3 bai2 tu4 (small white rabbit), da4 bai2 e2 (big white goose), da4 ye3 lang2 (big wild wolf), da4 mu3 ji1 (big female chicken).

The same regularity is exhibited almost without exception in the speech of the six-year-old children from Southern California. What is impressive in these four sample corpora is the uniformity with which the standard usage is reflected even in quite early stages of a child's speech. It might be argued that the problem is simpler in French. Still impressive is the way in which Philippe uniformly puts grand or petit before the noun and adjectives of color like bleu or jaune after the noun.

Let me illustrate with an artificial example what I think is a reasonable explanation of the underlying semantics, and why we place the adjective of variable intensity prior to the adjective of classification. In Figure 4 we see a set of dots in the top row marked G for green and R for red. If we ask for the denotation of *big dot* we get the next row, the single large green dot. If we ask for the denotation of the *red big dot* we get a nonexistent denotation, because we first start with *big dot*,



Figure 4. Denotations of various noun phrases illustrating the order of modifying adjectives.

which is green, and then ask for red, but there is no big dot that is red.

On the other hand, if we start the other way and ask for the denotation of *red dot*, we get the two red dots. Then if we ask for the big red dot we apply the intensive adjective big and select the larger of the red dots.

The idea behind this can be expressed in abstract terms in the following way: First, we intersect the set denoted by the noun with the set denoted by the adjective of classification. We order this set according to the ordering relation denoted by the adjective of intensity, in the present case, the adjective *big*. If we are talking about the upper end of the ordering, we then select as the denotation of the noun phrase the single largest object or something close to the single largest object, for example, a small subset. It is easy to make all this quite precise in terms of a few mathematical symbols, but that is not my objective here.

For those who are somewhat uneasy about the absolute definiteness of my example in terms of dots, they can substitute *biggest* for *big* and obtain a quite unambiguous analysis. Thus, in the second line we talk about the *biggest dot*, in the third line the *red biggest dot*, which is most unusual English, and so forth I should mention that I have not analyzed the example in terms of the completely semantically unambiguous superlative, because the use of the superlative in children's language is relatively rare. As already mentioned, there are 370 occurrences of *big* in the Nina corpus and 674 occurrences of *little*. In contrast, there are just five occurrences of the comparative

ambiguity of big I mean that exactly what initial segment of the objects ordered by size is selected as the denotation will vary from one circumstance to another. I do think the analysis in the present case that sharply differentiates the semantic function associated with an adjective like red as opposed to an adjective like big is in first approximation correct and represents a useful insight into the subtleties of the use of adjectives in English. Let me mention also that there are cases, and they are proper cases, of usage in English in which the order is reversed. For instance, if someone is looking at two large chairs among a collection of chairs and one of them is green and one of them is red, it is appropriate to say, Give me the green big chair. Further complex things about the semantics of adjectives are encountered in children's speech.

bigger and three of the superlative biggest, and

just three of *littler*, none of *littlest*, none of *smaller*.

and one of smallest. When I have spoken of the

adjectives are encountered in children's speech. For example, there are 260 occurrences of *another* in the Nina corpus and 227 occurrences of *other*. The semantics of these two adjectives is obviously not in any sense the simple intersection function. Cardinal numbers and their different usages and positions raise additional problems, but here there is a longer tradition and therefore a more straightforward sense of what is correct.

As fascinating as these further details about adjectives can be, in order to give a survey I move on to the special case of quantifiers, which can be treated as adjectives, but in my own analysis should not be.

QUANTIFIERS

To keep the story simple I restrict myself only to the classical quantifiers all and some. And here is Nina at her classical best all colors, all of they gonna go in here; all the animals did, all the ducklings going to the California; all these and these children are gonna eat; mommy I need all the pieces cut; and I got some lambs; and I want some people, and I made some pancakes; and some snakes were wrapped up together.

It is my contention that the meaning of some and all in these examples from Nina's speech is almost without change the same as in classical mathematical language when we say All even numbers are divisible by two or Some prime numbers are twin primes, or as another parallel from the classical examples of Aristotle: All men are mortal, some men are tall. At the age of 30 months Nina was handling quantifiers with beautiful precision. Compare this fact. It was not until 1879, upon the publication of Frege's Begriffschrift, that an explicit theory of quantifiers was formulated Today, the theory of quantification, in the sense of the theory of the universal and existential quantifiers, is taken to be at the heart of general logic. I have even heard one paper by a philosopher in which the theory of predication and quantifiers was taken to be the most distinguishing characteristic of human as opposed to nonhuman, animal thinking. I am pleased to report that Nina and other children like her seem to have these matters under good control at a very early age

There are two aspects of Nina's use of quantifiers that I think are representative of the use of a large number of children, but which receive no treatment in Aristotle and very little in the logical tradition from Frege onward.

The first is that both the existential and universal quantifiers, but especially the existential quantifier, occur more in object position than in subject position. The object position for quantifiers is especially natural in stating commands or expressing wants or needs, and it is exactly the logic of such statements that has been ignored until recently in the development of explicit logical theory. Three examples that have not yet been cited, but that would be typical of Nina's use of the existential quantifier in object position would be these: I want some diaper pins; I will get some blocks; I want some more toys.

The second point is that the universal quantifier is so often used in conjunction with the definite article. There is a kind of concreteness and contextualism about this, which is especially reinforced by the earlier analysis given of the definite article, that makes this the natural way to talk, rather than using the universal quantifier in unrestricted form. Thus when Nina says all the animals did, she is referring to the toy animals in the immediate context, and the definite article the makes that clear The same kind of remark applies to her statement about all the ducklings An example in which she may use a demonstrative adjective rather than the definite article is this: All these clothes are getting off. The force of the definite article or the demonstrative adjective is to restrict the universal quantification to the contextual set at hand, and this is where a restriction properly belongs Aristotle's or Frege's unrestricted universal quantifier can be defended in terms of logical simplicity, but for working purposes the canonical use of quantifiers is *all the xs*, not *all xs*. This has been too little remarked upon in logical theory, but is evident enough in Nina's speech.

One final remark is needed on Nina's use of all and some I have not covered the many different uses of these words as adverbs or parts of adverbial phrases, but in relative frequency these uses are as common as the direct use as quantifiers. In almost all cases, however, the semantical function of the words is similar to their straight function as quantifiers. I have deliberately avoided defining explicitly the semantic functions associated with the production rules by which quantifiers are introduced, not because I think the subject is unmanageable, but because the explicit treatment is rather technical. At least I do not yet understand how to present it in a way that is not technical. The semantics is simplest in my judgment when quantifiers enter at a high level in the derivation tree, and not at the level of adjectives that are part of noun phrases.

PROPOSITIONAL ATTITUDES

There is an important and fundamental distinction in logic that is not needed for the classical development of the foundations of mathematics, but that is essential for obvious distinctions in the use of ordinary language. This is the distinction between language that is purely extensional and language that is intensional. The most obvious way in which language is used intensionally is in the expression of necessity, possibility, or propositional attitudes. Examples of the expression of propositional attitudes are statements about beliefs, needs, wants, expectations, or fears. They are expressed by a wide variety of verbs in every natural language.

Because of the importance and interest in these matters in any complete analysis of the semantics of natural language, let me give one example that is classical in the philosophical literature, but is not directly pertinent to Nina's speech or that of other children her age. The example concerns the non-truth-functional or nonextensional character of belief statements. Thus, from knowing that the statement *The earth is flat* is false, we can infer neither the truth nor falsity of the statement *John Jones believes that the earth is flat*. Similarly, from the truth of the statement *The sun is larger than the earth* we can infer neither the truth nor the falsity of the statement *Aristotle believed that*

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the sun was larger than the earth. I have no direct analogues to these examples in the speech of Nina, because no form of the verb believe or the noun belief occurs in our extensive sample of her speech. As you would also expect, there are no instances of statements of possibility or necessity. There are, however, numerous instances of the expression of propositional attitudes, especially expressions of wants or needs, and there are many expressions of because or -cause.

The case of the various forms of want, for example, wanna, is striking. Of the large corpus of over 100,000 words, somewhat over 1% are occurrences of some form of want (want, 883; wanna, 359; wants, 60; wanted, 6).

One useful distinction in the use of terms or noun phrases in the expression of propositional attitudes occurs already in Nina's speech This is the distinction between attributive and referential use of terms, a distinction already recognized by medieval logicians who characterized the referential reading as giving us a statement de re as opposed to the attributive reading which yields a statement de dicto. Both attributive and referential uses occur in the Nina corpus. Here are some examples of attributive uses: He don't want a Band-aid on; I want milk; I want some more toys; I want another story OK; and here are some examples of the referential use: I want the next page (the next page, of course, having a definite reference or denotation); I want this (with this having reference to a particular object in the environment); I want her to wear the blue dress (where the phrase her to wear the blue dress refers to a definite concrete act).

In the examples I have cited there seems to be little ambiguity between attributive and referential use of the noun phrases in object position. In the philosophical literature on these matters there has been considerable discussion of the kinds of examples that do give rise to ambiguity. A typical instance would be: John wants to marry a French girl. Given only this sentence, it is ambiguous whether the reference is to some one particular girl or whether John is looking for a wife, does not have a definite person in mind, but wants her to be a woman who is French Such examples can also occur with the use of the definite article as well as the indefinite article For example, Hintikka (1973) cited "John believes that the richest man in town is a Republican." It is ambiguous whether John has in mind some particular individual or simply believes it true that whoever is

the richest man in town, he will turn out to be a Republican.

I have examined Nina's use of *want* for the same kind of ambiguity. It exists with the indefinite article, but so far as I can see not with the definite article. Here are several examples with the indefinite article: Do you want a pink balloon?; her don't want a cup; her want a blanket OK; I don't want a jersey on; I want a toy. In all these cases, as Hintikka rightly remarked in his own analysis of a different range of examples, additional factual information, in our case the kind of information available in the corpus from preceding sentences or comments on the situation, makes clear whether the usage is attributive or referential.

The question of theoretical interest is what uniform account semantically is to be given of these For example, can the kind of model matters theory characteristic of elementary formal languages, which are normally extensional, be extended to the kind of language expressing propositional attitudes as found in Nina's speech? If I had asked this question 30 years ago, the answer would almost certainly have been pessimistic and rather negative, because the semantics of modal concepts or propositional attitudes had scarcely been developed. Fortunately, an intense concern with these matters within logic proper in the past three decades has created a considerable logical apparatus, and a deep understanding of the semantical problems involved has developed In saying this I do not mean to suggest that all the conceptual problems are solved or that the application of current theory to children's speech is simple or straightforward. I do mean to suggest that many powerful and subtle methods are available and can be applied.

The most important theoretical point in these developments is that the semantics of sentences expressing propositional attitudes can be given a precise treatment in terms of the concept of a set of possible worlds.

To illustrate the idea of a set of possible worlds, let me first consider some classical modal concepts before turning to Nina's speech If I say "It is possible that it will rain tomorrow," then the semantics of this statement is that there is a possible world in which it will rain tomorrow. If on the other hand I say "It is necessary that an object that is red is colored," then I mean that in every possible world this state of affairs must hold. On the other hand, if I say "It is contingently true that Bertrand Russell lived to be more than 90 years old," I mean that in some possible worlds this assertion would be true and in others it would be false. When Nina says "I don't want a jersey on," one interpretation of the semantics of this is that there is a possible world in which Nina does not put a jersey on, and it is in this world that she wants to be. (When I say "one world," I mean usually a set of worlds having this characteristic.) In general when Nina says "I want X," the semantics can be given a precise interpretation in terms of her desire for the actual world to be drawn from a certain set of possible worlds, and she is asking for actions that will make this take place.

(A technical remark is in order about these matters. A tradition exists in the logical and philosophical literature that defines a proposition as a function from possible worlds to truth values. This, for example, was the definition preferred by the late Richard Montague. On the basis of this kind of analysis, we would say that Nina's statement of a want or need expresses a proposition that is a function from possible worlds in which the want is satisfied to truth values. For various reasons, I do not like this analysis. For instance, one of the difficulties of Montague's view is that any two logically equivalent sentences express exactly the same proposition. Rather, I prefer that the structural characteristics of a sentence be an integral part of its expression of meaning. The identification of an utterance expressing a want with the function mapping possible worlds into truth values ignores the grammatical structure of the utterance. On the other hand, I emphasize that in the semantic analysis of such utterances expressing wants the simple theory of denotation discussed earlier is not satisfactory, and a more complicated theory building on the theory of possible worlds is required. For example, once we pass from a single fixed world or model to a set of models or worlds, simple adjectives like red no longer denote a set, but at the very least a set in each possible world or, put another way, a function that is a mapping from possible worlds into sets of objects in that world, in each case the set of objects being the set of red objects in that world.)

At this point many of you may feel that I have pulled you a long way from psychological questions to philosophical questions that seem to have little relevance to Nina's thoughts, actions, and language. I wish to urge upon you the thesis that this is not at all the case. Psychologists have

mainly ignored the complexities and subtleties of the expression of propositional attitudes by young children even at their earliest stages. There may be a simpler way of giving a full-scale analysis of these matters, but if there is, it is not known to me, and it is certainly not widely available in the current relevant literature on these matters. What I have hoped to convince you of, and I think in the limited space available I have not been able to do the job adequately, is that already a host of methods and subtle distinctions are available, which we may effectively use for a better understanding of the explicit semantics of children's speech. What I have tried to make evident in my discussion of propositional attitudes is this: Even from the very beginning of a child's speech, in the age from two to three years, the whole battery of semantical problems associated with propositional attitudes, a set of problems among the most subtle in current semantical theory, arise in providing a detailed and accurate theory of children's speech.

Consequence and Paraphrase

In my introductory remarks I mentioned the desirability of changing the classical logical notion of consequence, and I now turn to this topic. In order to give the discussion a focus, I shall relate my remarks about logical consequence and a wider concept of consequence to psycholinguistic discussions of paraphrase and how problems of paraphrase arise in the analysis of the semantics of children's speech.

Frege's definition of paraphrase is that two sentences are paraphrases of each other just when they have the same logical consequences. If we use the characterization of propositions stated above, that is, a proposition is a function from possible worlds to truth values, then we may also characterize in equivalent fashion two sentences as being paraphrases of each other just when they express the same proposition. It is surprising to find this semantical characterization of paraphrase essentially unreferred to in the psycholinguistics studies on the paraphrasing ability of children or adults.

For example, in the careful and extensive study of Gleitman and Gleitman (1970), *paraphrase* is characterized as a notion that is properly thought of as a part of generative grammars, but this seems to me a clear error. Gleitman and Gleitman emphasized that transformations of a sentence can express paraphrases, but in the standard semantical Fregean sense, two sentences that have totally unrelated derivational histories can be logical paraphrases of each other. In practice, moreover, what is used in experimental tests of paraphrasing ability is really a semantic and not a syntactic criterion. The explicit use of model-theoretic semantics would put the experimental studies in this area on a sounder conceptual basis.

Nevertheless, I think there is adequate ground for changing the Fregean definition, which is too stringent. When Nina says things that are ungrammatical to our adult ears, it is usually easy for us to paraphrase what she has said, even without knowledge of the context. Consider the following: No, I wanna go to what that thing and see if I'm tall; no more presents he doesn't give me; now let me try other Rachel's sunsuit, mommy; I feel better my diaper rash. On the other hand, the following sentence of Nina's might present some difficulty even within context: I want to save this on with the same time.

In paraphrasing Nina's speech or someone else's, we almost always assume without guestion certain background information and knowledge that is not included in Frege's strict definition of paraphrase in terms of logical consequence. As I mentioned earlier, within model-theoretic semantics it is easy to give a characterization of logical consequence; namely, one sentence is a logical consequence of another if the first sentence is satisfied in any model in which the second is satisfied. In other words, we consider all possible models. But, we can get a less strict notion of consequence by reducing the set of possible models to some smaller set in which basic intuitive knowledge is held rigid across all the models in the set. Two sentences can then be said to be paraphrases relative to this reduced set of models if they both are satisfied in exactly the same models of the reduced subset.

This reduced notion of consequence, which I shall call R-consequence, has other uses than in the treatment of paraphrase. It is also the appropriate concept, in my judgment, for the analysis of questions and answers in children's speech. In the age range I have been mainly discussing, children primarily answer questions by adults, and it is only a year or so later that the tables are turned and they begin asking the questions and expecting answers. For this early stage of answers or the later stage of questions, the concept of R-consequence provides the proper concept for characterizing semantically correct answers to a question. (Notice that I do not say *the* semantically correct

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answer, because in general any one of an indefinite number of paraphrases will be accepted as correct.) I return to the importance of questions and answers in children's speech when I discuss problems of verification.

I conclude this article with a discussion of three types of problems: problems of context, problems of process, and problems of verification.

Problems of Context

When Nina says "I need some more" or "I want some too," it is clear that a full semantical account of these utterances is dependent on the context of utterance. This dependence on context is characteristic not only of children's speech, but of much casual adult talk as well. It stands in sharp contrast to sentence tokens of a formal language that are self-contained and timeless in character, or even to mathematical statements or other scientific statements in ordinary language in formal textbook or treatise mode. The way in which the kind of model-theoretic semantics I am advocating can be extended to cover such matters of context has already been indicated in the treatment described for definite articles. I see nothing standing in the way of similar extensions to other problems of interpretation, as in the case of the two examples just cited.

On the other hand, elaboration of the context to give an adequate account of what Nina was perceiving or remembering at the time she was speaking is to extend in quite substantial ways the framework of classical semantics to include concepts and requirements that have been investigated in all their complexity for many years by psychologists. Putting together what we know about remembering and perceiving with the kind of semantic structure for language I have outlined is a formidable theoretical task that has yet hardly begun. It seems to me, however, that this is the direction in which we should try to take account of context and, in the doing, build a much richer psychological model of Nina's and other children's language behavior.

Problems of Process

Building such a model of remembering and perceiving takes us at once to the consideration of process. A proper criticism of the semantic theory I have outlined is that there are no serious considerations of processing. There is no temporal analysis of the machinery children or adults use for semantic processing of sentences they speak or hear.

This absence of an explicit analysis of process has been brought home to me in a salient way in some of our own research at Stanford University in the past year or so. In attempting to understand these problems of process and how modeltheoretic semantics can be applied to the actual production of speech, we have turned to the problem of implementing an ongoing question-answering system for our computer system. We have chosen a domain that has no requirements of context, namely, elementary mathematical language-with an emphasis on the natural language and not on the elementary mathematics. But even here we have found that substantial theoretical extensions have had to be made to the model-theoretic semantics as described here or as found in the standard logical literature in order to have a workable computer program for actual question answering. My younger colleagues, Robert L. Smith and Freeman Rawson, have now advanced this analysis of process a fair distance (see Rawson, 1973). Space does not permit me to compare this work with earlier work by William Wood, Terence Winograd, or other computer scientists concerned with creating computer programs of a similar sort.

One way of describing the situation is similar to what I said about the problem of context. It is not that model-theoretical semantics as such is wrong, but rather that it has to be extended in order to obtain a working model. Just as a theory of remembering and perceiving must be built into an adequate model of a child in order to give a full account of his speaking and listening, so the modeltheoretic semantics of even so definite a subject as elementary mathematics must be extended to fixed and definite dynamic ideas about the order in which functions are called, the precedent procedure for processing of given functions, and in general, the many kinds of considerations that enter into the construction of a compiler or interpreter for a computer language.

Problems of Verification

As in psychological theorizing and experimentation in all areas, it is seldom the case that we can construct a theory that is adequate to account for all aspects of the psychological process under investigation. This widespread fact of theoretical incompleteness doubly holds for phenomena as complex as those of language. Without providing a full theory of remembering, perceiving, or internal processing we can still ask for empirical tests or verification of theoretical concepts such as those of model-theoretic semantics that I have been discussing.

What must be faced is that the verification of a semantic theory is more difficult and less direct than the verification of grammatical theory. For instance, if one writes a grammar for the corpus of a child's speech, it is possible in a direct way to say what percentage of the utterances in the corpus the grammar parses, and if probabilistic criteria are imposed additionally how well it generates utterances with approximately the same frequency as the frequencies observed in the corpus. Verification that the denotations assigned to terminal words or the semantic functions assigned to production rules of the grammar are correct is not amenable to such straightforward and direct attack. It is of course the case that in testing any theory there are areas of intuitive judgment that cannot be reduced to a formal algorithm of verification, and in many cases the semantic analysis given of the utterances of young children by the kind of apparatus I have described can receive widespread intuitive agreement as to the correctness of the analysis. All the same, the central problem of verification is a subtle one and is not easily handled. For example, in his dissertation, Robert L. Smith (1972) gave an extensive semantic analysis of the corpus of Erica. The Erica corpus consists of 27,922 words. Erica was about 32 months old at the time the corpus was collected and thus fits within the range of the corpora of Nina, Philippe, and Lingling. Smith has written a completely systematic model-theoretic semantics for Erica, assigning a semantic function to each production rule of the generative grammar he also wrote for the corpus. The total system is complex and difficult to comprehend in any simple way. The problem arises of how to test in a systematic way that his semantical analysis is correct. Intuition can be tested on each rule, but it is a strain on the viability of intuition when the number of rules is large and some of them are complex. So far as I can see, we have at the present time no direct way to test the correctness of such a systematic semantics. It is a genuine theoretical construction, and we must use classical methods of indirect analysis to test its validity. The difficulty of providing such a direct test is one of the reasons we have been involved in writing a question-

answering computer program for elementary mathematical questions and commands, because the intuitive agreement and understanding of such questions and commands is absolutely sharp and objective in character, and so the correctness of the underlying semantics is subject to a universally agreed upon test. To some extent, this same approach can be extended to the corpus of speech of a voung child when the adult speech is recorded as well, for the question-answering pairs can be analyzed in similar fashion, and in many cases a highly objective criterion is possible for evaluating the semantic analysis of the question-answer pairs. All the same, a fair portion of the question-answering between adult and child is not subject to the same sharp test that obtains for elementary mathematical questions.

The other route is to carry only so far the analysis of spontaneous speech and to turn to experimentation for the detailed verification of semantical concepts and theories. It is my present view that this step is essential, and we shall not be able to collect the evidence to persuade the skeptic until comprehensive experiments that adequately test the kind of semantical ideas I have discussed today are performed. Such experimentation is not hopelessly complex and does seem feasible. There is already a useful tradition of experimentation with three- and four-year-old children, especially in the form of the creation of toy or puppet characters that talk and perform simple actions, and it seems possible to build reasonably sharp tests of comprehension into such situations. On the other hand, designing adequately structured experiments that elicit speech from two-year-olds to provide a

clear test of their underlying understanding of what they are saying is not a simple matter. It is an area of methodology that badly needs development, and I call on those of you who are interested for support and help.

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