

The Psychological Unreality of Quantificational Semantics

. . . an endearing trait of canonical notations is that they do not bind.

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1. Introduction

A theory of the structure of a human language, as Chomsky has emphasized, is a theory of the mental processes and representations underlying human use of the language. Thus an adequate syntax of English will identify the syntactic structures and operations underlying recognition and production of English by fluent speakers. Adequacy consequently requires that the structural descriptions and transformations posited by a syntax be psychologically real. That is, the structures posited must be those that are actually internalized by the fluent speaker and that, in part, control his linguistic behavior. There is now good evidence that this requirement is met by at least some of the posits of transformational grammars (cf. Fodor, Bever, & Garrett, 1974, ch. 5). Similarly a semantic theory of a human language must identify the representations of the language's sentences, production of which is necessary and sufficient for *understanding* those sentences. Thus the posits of an adequate semantic theory — like those of an adequate syntax — will be psychologically real: they will be structures actually accessed during sentence comprehension.

Most models of sentence comprehension for achieving production or accessing of semantic representations posit a two-component process (e.g., Anderson & Bower, 1973, ch. 8; Winograd, 1972, pp. 16-34, 126-169; Schank, 1972). The first component of the process takes the sentence as input and yields a surface syntactical parsing of it. This parsed structure becomes input for the second component, which produces the canonical semantic representation of the sentence.

It is true of these models that in general, the more *complex* a sentence's semantic representation, the greater the amount of second-component processing required to produce that representation. Consequently any semantic theory with such a processing view will predict the relative amounts of processing required for comprehension of a pair of English sentences with identical or similar surface forms: comprehension of the sentence with the more complex semantic representation will require more processing and thus will take longer. Since difficulty of comprehension is correlative with amount of processing required for comprehension, a semantic theory of English will predict the relative comprehensional difficulty of pairs of English sentences: the sentence with the more complex semantic representation will be harder to understand.

It is also true of these models that the amount of second-component processing required for comprehension is a function of the representational *distance* between the surface form of the sentence and its semantic representation. For the greater the disparity in surface and semantic representations, the more second-component processing required to get from the one to the other. "Not all men didn't come," for example, might mean the same thing as "Some men came." Even though the two sentences would have the same semantic representation, however, the first could still be more difficult than the second. Plausibly the semantic representation underlying these sentences is more like the surface form of the second, so less second-component processing is required to understand it than to understand the first. On this hypothesis too a semantic theory will make predictions of relative comprehensional difficulty; of two sentences having the same semantic representation, the one whose surface representation is more dissimilar to that semantic representation is the harder to understand.

The hypothesis that the amount of processing required for comprehension is correlative with the complexity of the underlying semantic representation will be referred to as the *complexity hypothesis*. The hypothesis that the amount of processing required for comprehension is correlative with the dissimilarity of the surface and semantic representations will be called the *distance hypothesis*.¹ The two hypotheses are not mutually exclusive; comprehensional difficulty, that is, might be a function of both complexity and distance.

There is also wide agreement among semantic theorists that a number of semantic properties and relations should be formally characterizable in terms of semantic representations. These properties and relations include anomaly, ambiguity, and most important, entailment (implication, deductive validity). Thus an adequate semantic theory of English will provide a *formal characterization of entailment* in terms of the semantic representations it assigns to sentences.

There are a number of semantic theories of natural languages that derive from the classical quantification theory of Frege. These use quantificational structures as semantic representations. They proceed by representing syntactically or morphologically simple expressions of natural languages by syntactically or morphologically complex constructions in the quantificational semantic metalanguage. In terms of these rather few quantificational constructions, such theories attempt formal characterizations of entailment for a wide variety of sentences. But if the theories are to be adequate theories of English, their representations must also underlie comprehension and thus be psychologically real. In what follows I urge that if either the complexity hypothesis or the distance hypothesis is true, then the known theories of semantic representation inspired by Frege's work make very implausible predictions of the relative comprehensibility difficulty of certain pairs of English sentences. If this claim is true, then it follows that those representations do not underlie the comprehension of English: they are psychologically unreal. Thus quantificational semantic theories are inadequate as general theories of English competence and cannot contribute to a psychological model of a speaker of English in any straightforward way.²

2. Logical Form

The fundamental structures of quantification theory are: proper names, predicates (of any finite number of argument positions), sentential connectives (conjunction, disjunction, negation, conditional, biconditional), and two quantifiers (universal and existential). Some of these structures can be defined in terms of others, but for present purposes we can just as well think of them all as primitive. In terms of these structures quantificational semantic theories attempt to build semantic representations of English sentences. For example,

the categorical statements of syllogistic theory are represented as follows:

All ducks are hurt	$\forall x (Dx \rightarrow Hx)$
Some ducks are hurt	$\exists x (Dx \& Hx)$
No ducks are hurt	$\neg \exists x (Dx \& Hx)$
Some ducks are not hurt	$\exists x (Dx \& \neg Hx)$.

The power of quantification theory comes from its ability to represent a wide variety of quantificational constructions in a meager and uniform notation, and to characterize entailment in terms of that notation. Among these constructions are definite descriptions and number sentences. Russell (1905) showed that 'The duck is hurt' can be represented in quantificational notation as ' $\exists x (Dx \& Hx \& \forall y (Dy \rightarrow x=y))$ ' (or alternately as ' $\exists x \forall y [(Dy \leftrightarrow y=x) \& Hx]$ '). And sentences like 'Exactly two ducks are hurt' can be represented as ' $\exists x \exists y [Dx \& Hx \& Dy \& Hy \& \neg x=y \& \forall z (Dz \& Hz \rightarrow z=x \vee z=y)]$ '.

It seems reasonable that the complexity of such a representation is in part a function of its length. That is, generally speaking, the more occurrences of predicates, connectives, and quantifiers in such a representation, the greater the amount of processing involved and the greater the comprehensional difficulty. Of course, some predicates or quantifiers may be more difficult than others. In the case of connectives such inequality seems clear, since negation is so difficult (Wason, 1961) and since different connectives affect the difficulty of rule-learning tasks to different degrees (Bourne, 1967). And, of course, structure—such as degree of embeddedness—will also be relevant to difficulty. But the complexity variations I shall consider will not require any knowledge of such differences. We shall be able to gauge roughly the complexity of a sentence by a triple $[p, c, q]$, where p is the number of occurrences of predicates in the sentence's semantic representation, c is the number of occurrences of connectives, and q is the number of occurrences of quantifiers. The representational triples of some familiar sentences representable in quantificational notation are as follows.

Every duck is hurt	[2, 1, 1]
A duck is hurt	[2, 1, 1]

No duck is hurt	[2, 2, 1]
The duck is hurt	[3, 2, 2] or [4, 3, 2]
Exactly one duck is hurt	[5, 4, 2]
Exactly two ducks are hurt	[9, 9, 3]
Exactly n ducks are hurt	$[\frac{n^2}{2} + \frac{5}{2}n + 2, (n + 1)^2, n + 1]$.

As can be seen, the number of predicates, connectives, and quantifiers occurring in representations of simple number sentences goes up as a function of n^2 . As n goes from 2 to 10 the total number of predicates, connectives, and quantifiers goes from 21 to 209. Thus, given the complexity hypothesis, 'Exactly ten ducks are hurt' is predicated to be roughly ten times as difficult as 'Exactly two ducks are hurt'. Of course that prediction is false, for the two sentences are approximately equally difficult to understand. The predictions become even more absurd, naturally, as n gets even bigger: thus 'Exactly one million ducks are hurt', though easy enough to understand, has on the order of 10^{11} times as many predicates, connectives, and quantifiers as does 'Exactly two ducks are hurt'.

Of course no quantificational theory is committed to this treatment of number sentences. However, there are what appear to be formally valid inferences containing such sentences. For example, (1) Only one man was invited to dinner

Two men came to dinner

\therefore Some uninvited men came to dinner

is valid, and thus should be characterized as valid by a semantic theory. The only known way of doing this in a quantificational context is by representing number sentences in the Russellian way. So if quantification theory is to avoid making false relative difficulty predictions, new techniques of representation are required. It might be thought that such techniques are available in a semantic metalanguage that contains a set theory; here (1) could be represented as

The cardinal number of $\{x \mid x \text{ is a man \& } x \text{ was invited to dinner}\} = 1$

The cardinal number of $\{x \mid x \text{ is a man \& } x \text{ came to dinner}\} = 2$

$\therefore \exists x (x \text{ is a man \& } \neg x \text{ was invited to dinner \& } x \text{ came to dinner})$.

It seems extremely unlikely, however, that the unabbreviated forms

of such representations will accurately reflect sentence difficulty: 'Two men came to dinner', for instance, seems much less difficult than 'There is a one-one function whose domain is $\{x \mid x \text{ is a man \& } x \text{ came to dinner}\}$ and whose range is $\{\emptyset, \{\emptyset\}\}$ '. (And this second sentence still does not correspond to the unabbreviated form of the set theoretic representation.) Thus the apparatus of set theory seems not to help here; if anything, it puts us out of the frying pan and into the fire.

Further difficulties of this kind exist for any related attempt to represent sentences like 'Most ducks are hurt', 'Few ducks are hurt', or 'Half of the ducks are hurt'. The only known way of representing these sentences within quantificational structures is, again, to adopt a set theory as underlying logic of the metalanguage. 'Most ducks are hurt' then becomes representable as something like: the set of ducks that are not hurt can be mapped one-one into the set of ducks that are hurt, but not vice versa. Even in abbreviated form this is obviously a much more intricate representation than that posited for 'Some ducks are hurt.' But it seems very likely that 'Some ducks are hurt' and 'Most ducks are hurt' are approximately equally easy to understand; surely nothing like the differences predicted by the present account exist. And, of course, to waive these sentences would be to give up seemingly valid inferences like

(2) Most ducks are hurt

Most ducks are hybrids

∴ Some hybrids are hurt.

There is evidence that negative quantifiers like 'no', 'few', and 'a minority' make sentences more difficult than do positive quantifiers like 'all', 'most', and 'a majority'. And there is also evidence that the 'all'-'some'-'no' group is easier than the 'most'-'many'-'few' group, which in turn is easier than the 'a majority'-'a minority' group. But there is no known evidence for the predictions of quantificational semantics. Just and Carpenter (1971), for example, found picture verification of 'most' and 'many' sentences no harder than 'no' and 'none' sentences. But if either the complexity or the distance hypothesis is true, quantificational semantics should predict 'most' much harder than 'no' for its quantificational representation is more complex and more distant from its surface form than is that for 'no'. Similarly Glass, Holyoak, and O'Dell (1974, experiment

II) found verification times for 'few' sentences on the average only 6% slower than for 'no' sentences, whereas 'no' sentences were 14% slower than 'some' sentences. Quantificational semantics, though, must predict that 'no' sentences are only slightly harder than 'some' sentences and that 'few' sentences are much harder than 'no' sentences. Thus the available evidence runs counter to the predictions of quantificational semantics.

Sentences involving number words or quantifiers such as 'most' are not the only ones about which quantification theory appears to make false predictions. For example, although parsing 'Only John came' should be but slightly harder than parsing 'John came,' quantificational semantics predicts the first to be much harder comprehensionally than the second. For while quantificational representation of the second is just ' Cj ', the representation for the first is ' Cj & $\forall x (Cx \rightarrow x = j)$ '; the quantificational triples are [1, 0, 0] and [3, 2, 1], thus marking a substantial difference in complexity between the two representations. Other cases similar to this abound.

What all of this seems to show is that if the complexity hypothesis is true, comprehension of an English sentence cannot involve production of the sentence's logical form if that form is given by traditional quantification theory. Relative ease of comprehension is simply not accurately predicted by such logical forms.

Most of the foregoing examples can be made to apply equally if the distance hypothesis is true. For example, 'Some ducks are hurt' and 'Most ducks are hurt' have very similar surface forms, so initial parsing of them should be equally difficult. But the surface form of the first sentence is much more like its presumed semantic representation than is the surface form of the second like its presumed semantic representation. That is, not only is quantificational representation of the second sentence more complex than that for the first sentence, but it is also more distant from the relevant surface form. Consequently, if the distance hypothesis is true, then many of the previous predictions will again be made. And so, if the distance hypothesis is true, comprehension cannot involve production of quantificational structure.

3. Senses

Frege thought sentence comprehension requires production of

sentence “sense,” the “thought” expressed by the sentence. Every predicate, connective, and quantifier, Frege thought, has a function as sense, whereas proper names have objects as senses (cf. Frege, 1892a, b). The thought expressed by a sentence is then the value of the function that is the sense of the sentence’s primary component when it takes as arguments the senses of the other relevant sentential parts. Consider for example a sentence of the form:

$$\forall x Fx \rightarrow Fa.$$

Here the arrow is the primary sentential component. It has as a sense a two-placed function that takes as arguments the senses of the sentences that are the antecedent and consequent of the conditional. The predicate ‘F,’ in turn, has a function as a sense. On the consequent side this function takes as argument the object that is the sense of the proper name ‘a’ and yields as value the thought expressed by the sentence ‘Fa.’ On the antecedent side, the sense of ‘F’ is the argument for the function that is the sense of the universal quantifier; the value is the thought expressed by the conditional’s antecedent. These two thoughts, then, are the arguments for the sense of the arrow, which has as value the sense of the whole conditional. This account in terms of functions and arguments is generalized to all quantificational structures (but cf. Martin, 1974). The thought expressed by a sentence can thus be computed by computing the functions that are the senses of sentential parts for arguments that are senses of other sentential parts.

On this view the logical form of a sentence is something like its deep syntax, and it is perhaps associated with the sentence’s surface form by a series of presently unknown transformations. This syntactic representation directs semantic operations by pointing functions at arguments and by controlling the order in which computations are made. It is a view that is no more tenable than the view of comprehension by production of logical form, however. For on this view comprehension still requires production of logical form as a syntactic control for subsequent semantic processing; so the enormous differences predicted by a logical form semantics would still be expected on a theory of comprehension by computation of sense. Further, the number of semantic computations required for understanding a sentence will, on this view, increase with the total number

of predicates, connectives, and quantifiers appearing in its logical form. Thus semantic processing—and with it comprehensional difficulty—would increase with length of logical form. Consequently the Fregean theory embraces the complexity hypothesis as an explicit consequence. And so Frege's theory of sense entails the resulting untenable predictions of comprehension by production of logical form.

All of the difficulties with logical form, then, are difficulties with any view that makes computation of senses necessary for comprehension as long as computational complexity is reflected in quantificational form. Frege's theory of sense thus is undone by the difficulties with logical form, so senses as he envisioned them cannot be psychologically real. Consequently computation of Fregean senses cannot be required by comprehension.

4. HAM

A canonical encoding notation much like that of quantification theory is proposed in Anderson and Bower's (1973) theory of semantic memory, HAM. HAM's encoding formalism is that of a binary labeled graph whose main branches are for subject, relation, and object. Complexity of a representation in this notation is plausibly a function of the size of the graph, the number of links or arcs it contains. For the more links there are in a graph, the greater the work needed to construct it, and the more processing steps required to check its structure during accessing.

Now HAM's graphs reflect quantificational structure with the restriction to use of only unary and binary predicates. Indeed, Anderson and Bower (1973, pp. 167ff) claim that their notation is "equivalent" to a version of quantification theory. Consequently the size of a graph will directly correlate with the length of an "equivalent" quantificational representation. And so complexity of quantificational representation and complexity of graph will go hand in hand. Thus if HAM were to be considered a theory of language comprehension, the implausible predictions of quantificational form semantics would be made by it also. For example, HAM contains only three quantificational devices, reflecting universal and existential quantification and a kind of particular though indefinite instance quantification. Consequently number words and other

quantifiers such as ‘the’, ‘few’, ‘many’, and ‘most’ must be dealt with by paraphrase in some way mirroring the options available to a quantification theoretic semantics. In terms of predicate and connective structure too, HAM will have to paraphrase in ways similar to quantificational semantics. Since HAM’s paraphrases are similar to those of quantificational semantics, the distance between surface and canonical graph representations will generally vary with the distance between surface and quantificational representations.

Thus if either the complexity or distance hypotheses is true, HAM will make implausible predictions about the relative comprehensibility of pairs of English sentences. Therefore HAM’s structures cannot underlie language comprehension. In a curious passage Anderson and Bower (p. 169) admit that “it seems reasonable to suppose that neither human language nor human memory evolved in a way that enables them to deal easily with the expressive powers of the formal languages that have been developed only in the past century of man’s history.” One might well wonder, then, about the appropriateness of those formal languages as models for semantics or memory.³

5. Truth Conditions

Tarski (1936) showed how to construct truth conditions systematically for a set-theoretic language in a metalanguage that contains translations of the object language constructions, names of the object language constructions, and some auxiliary logical devices. Davidson (1967a, pp. 305, 310) has claimed that such a systematic construction of truth conditions for the sentences of a language is an adequate semantics for the language. The truth definition shows “how the meanings of sentences depend upon the meanings of words,” and explains “the fact that, on mastering a finite vocabulary and a finitely stated set of rules, we are prepared to produce and to understand any of a potential infinitude of sentences.”

The definition of truth proceeds in Tarski’s work by defining the auxiliary notion of satisfaction. Intuitively a sequence of objects satisfies a predicate such as Dx_i just in case the i th object in the sequence is a duck. In fact Tarski’s scheme requires a clause like this for every primitive predicate in the object language.⁴ Next there is a series of clauses for the connectives. For example, the clause for

conjunction says that a sequence satisfies an open sentence t & w just in case the sequence satisfies t and also satisfies w . Finally come clauses treating quantifiers. For the universal quantifier the clause says that a sequence s satisfies an open sentence $\forall x_i t$ just in case s satisfies t and every sequence that differs from s in just the i th position satisfies t . A sentence is then true if and only if it is satisfied by every sequence. Using the clauses in the definitions of satisfaction and truth, a truth condition can be generated for every sentence of the object language. For example, the truth condition for a universal affirmative sentence will have something like the following form: for every sequence s , if the i th member of s is a duck then the i th member of s is hurt.

Davidson's claim that Tarski's construction provides an adequate semantics for English entails that truth conditions are psychologically real structures accessed during comprehension, and thus complexity of truth conditions or dissimilarity of surface form and statement of truth conditions predict comprehensional difficulty. Since Tarski's definition is wedded to quantificational structure as the underlying logical form, statements of truth conditions directly reflect quantificational form. If either the complexity hypothesis or the distance hypothesis is true, Davidson's claim will founder on the difficulties that demonstrate the psychological unreality of quantificational structures.

Another difficulty for Davidson is the apparent impossibility of extending Tarski's definition to handle opaque contexts—those in which coreferential substitutions are not always reference- or truth-preserving. If, for example, our object language contained an opaque operator that the metalanguage translated as 'it is widely believed that,' then the definition of satisfaction would need to contain an additional clause for belief. But no satisfactory clause seems to be available. We might say that s satisfies Bt just in case it is widely believed that s satisfies t ; but this is wrong, since in most cases—if not all—there will be no widely shared beliefs about satisfaction even if there are widely shared beliefs about matters the object language discusses. The only way out of this difficulty within the framework of Tarski's definition seems to be to produce extensional, truth conditional-revealing translations of opaque contexts. Such translations are typically immensely more complex than the

opaque constructions they translate (cf., for example Carnap, 1947).⁵ Thus, for example, since 'John knew where the man was' contains an opaque construction whereas 'John looked where the man was' does not, these two sentences will be predicted to be miles apart in difficulty if either of the complexity or distance hypotheses is true, although in fact they are reasonably close. Another example of this phenomenon is Davidson's (1967b) analysis of action sentences. On this analysis 'Al is taller than Bob' might be represented by ' aTb '; but 'Al is kicking Bob' comes out as something like ' $\exists x (Kx \ \& \ xBa \ \& \ xOb)$.' The quantificational triple for the first, then, is [1, 0, 0], while the triple for the second representation is [3, 2, 1]. Thus, given either the complexity hypothesis or the distance hypothesis, the two sentences are predicted to be quite different in comprehensional difficulty. Surely, though, that is not so. It might be countered that 'Al is taller than Bob' should be represented as ' $\exists x \exists y (xHa \ \& \ yHb \ \& \ xGy)$ ' ("there are things x and y such that x is a height of Al, y is a height of Bob, and x is greater than y "). Still the general point remains: there are simple relation sentences (perhaps 'Al is five feet tall' ($5'Ha$) is one) that do not appear to be very much easier than 'Al is kicking Bob.'⁶

Truth conditions so developed consequently do not seem an accurate indicator of comprehensional difficulty on either the complexity hypothesis or the distance hypothesis, and thus truth conditions cannot be the semantic representations that are accessed during sentence comprehension. They are, as semantic representations, psychologically unreal. It is worth emphasizing that the problems for truth conditions as a semantic theory are additional to those for quantificational form. We could, for example, easily add opaque constructions as primitive logical forms of the semantic metalanguage and add also rules of inference for them. The metalanguage would then have a more reasonable representation of the sentences as far as difficulty is concerned, and the additional inference rules would facilitate characterization of entailment. This route is blocked on Davidson's theory of truth conditions because extensionality is demanded (compare Martin, 1972).

6. Possible World Semantics

Possible world semantics attempts to circumvent Davidson's prob-

lems with opaque constructions by letting satisfaction be a relation between sequences of *possible* objects and open sentences. In practice this comes about by talking of possible worlds, each inhabited by possible objects and bearing some sort of accessibility relation to other possible worlds (cf. Kripke, 1963). Necessary truth is then truth in all possible worlds accessible from the actual world. Possible truth is truth in some possible worlds accessible from the actual world. And similar representations are supplied for other opaque constructions. The metalinguistic semantic representation for an object language sentence is then a quantificational structure, but one that talks about states of affairs in various possible worlds, not confining itself to talk of the actual world.

Since the representations that underlie possible world semantics are quantificational in form, they inherit all the implausibility of quantificational structures as semantic representations. But they produce implausible predictions of their own. For example, the two sentences 'If Plunkett played well, then we won' and 'If Plunkett had played well, then we would have won' must be in the same neighborhood in terms of comprehensional difficulty. Yet possible world semantics must say that the second is far more complex than the first.⁷ The first is represented by a quantificational structure concerned only with the actual world, while the representation of the second must appeal to a complicated set of possible worlds and events in them. Thus if the complexity hypothesis is true the second sentence must be predicted by possible world semantics to be much harder than the first. Lewis (1973), for example, begins his book on counterfactuals by saying (p. 1) " 'If kangaroos had no tails, they would topple over' seems to me to mean something like this: in any possible state of affairs in which kangaroos have no tails, and which resembles our actual state of affairs as much as kangaroos having no tails permits it to, the kangaroos topple over." He later (p. 16) expands on this formula by saying that a counterfactual conditional with ϕ as antecedent and ψ as consequent is true in world i just in case either of the following two conditions is met:

- (1) no ϕ -world belongs to any sphere S in $\$_i$, or
- (2) some sphere S in $\$_i$ does contain at least one ϕ -world and $\phi \supset \psi$ holds in every world in S .

Of course full expansion requires saying what ϕ -worlds, spheres, and S_i are; but the difference in comprehensional difficulty is already quite clear. And if the distance hypothesis is true, possible world semantics will again predict great differences in comprehensional difficulty between indicative conditionals and counterfactual conditionals, since there are great differences of distance between their respective surface forms and their posited semantic representations.

There are other applications of the techniques of possible world semantics that produce equally implausible predictions (e.g., representations of epistemic or deontic constructions). Consequently possible world representations cannot be psychologically real, so possible world semantics cannot provide an adequate semantics of English.

7. Conclusion

In general, comprehensional difficulty of a sentence seems to be correlative with the complexity of its surface form. The more a semantic theory "analyzes" sentences in producing their semantic representations, then, the greater the disparity between difficulty predicted and difficulty actually found. Logically loaded sentences must be represented in a logically loaded way rather than in a way that makes the logical form explicit. Only in this way will a semantic theory be able to predict that 'A man hit a ball' is as difficult as 'The man hit the ball', 'Exactly two ducks are hurt' is as difficult as 'Exactly one million ducks are hurt', 'John looked where the man was' is as difficult as 'John knew where the man was', 'John hit the man' is almost as difficult as 'John should have hit the man', 'No man is mortal' is easier than 'It is not the case that there is something which both is a man and is mortal', and 'Al is kicking Bob' is easier than 'There is an event which is a kicking event, is a by Al event, and is an of Bob event'. In order to be faithful to the facts about relative comprehensional difficulty, that is, sentences must *not* wear their entailments on the sleeves of their semantic representations.

In order to characterize entailments between sentences in terms of semantic representations, then, something like Carnap's (1952) meaning postulates is needed. In the case of number sentences these postulates should incorporate arithmetical laws in some way that makes inference (1) valid. There would have to be separate postulates for 'most' and other quantifiers, from which the validity of

inferences like (2) would follow. And there would have to be postulates for special modal and epistemic constructions, and no doubt many others. Only by thus separating comprehension processes from inferential processes will it be possible to remain faithful to the differences in processing time required by them. As Fodor, Fodor, and Garrett (1975) point out, the distinction is between mandatory on-line processes and optional off-line processes. It is intuitively quite plausible that comprehension is an on-line process and that consequently the representations accessed during comprehension are very similar to the surface forms that are the prompting input. Inference, however, is typically more labored and time-consuming. Of course we cannot draw all the valid conclusions of some piece of information, and what inferences we do make are often context-dependent. This suggests that context has much to do with which meaning postulates are utilized, just as context generally has much to do with what is retrieved from long-term memory. Thus if entailment is characterized in terms of the semantic representations underlying comprehension processes it is not done in the neat formal way quantification theory proposes. Rather, a host of special postulates must be invoked. Consequently quantificational structures do not underlie comprehension or inference, and so are psychologically unreal.

It might be claimed that the theories discussed above were never meant to contribute to a psychological model of language comprehension, so that the criticisms lodged against them are fairly irrelevant. Thomason (1974, p. 2), for example, says that "according to Montague the syntax, semantics, and pragmatics of natural languages are branches of mathematics, not of psychology." What this outlook denies is much clearer than what it asserts. What, after all, is a mathematical theory of language? What constraints is it sensitive to? How do we know when such a theory is true? What are the phenomena it theorizes about? The answers to such questions are relatively clear in the case of a psychological theory of language; and it is difficult, I think, to envision a viable alternative here. The proponents of the theories discussed above may not describe their theories as mathematical. But if those theories are not intended to contribute to a psychological model of sentence comprehension then, at the very least, we are due an account of what they are theories of. To date, accounts of such alternatives have not been given.

Notes

1. The distance hypothesis is somewhat motivated by the demonstration that memory of linguistically presented material is independent of surface form (Bransford and Franks, 1971; Kintsch, 1974). Presumably the mnemonic representation is at least sometimes linguistically neutral. Sentence comprehension, possibly, involves producing a similar such abstract representation from the sentence's surface form. Anderson and Bower (1973, pp. 224ff) appeal to the distance hypothesis in discussing reaction time differences for active and passive sentences.

2. This paper derives its general direction from Fodor, Fodor, and Garrett (1975), who discuss in more detail the two conditions on the adequacy of a semantic theory as well as the general strategy of representing syntactically or morphologically simple expressions by complex constructions. Fodor et. al. contend that the lexical decompositions of generative and interpretive semantic representations are psychologically unreal. This paper and I have benefited from the advice of Michael R. Lipton and Jerry A. Fodor.

Davidson (1964) and Martin (1974) give two arguments—different from the ones that follow—that versions of quantificational semantics are inadequate.

3. It seems quite possible that the structures produced during sentence comprehension are subsequently stored for accessing in memory. If so, then the unsuitability of HAM's structures for underlying comprehension must imply that they are not the structures used in memory either. Other theories of semantic memory (e.g., those of Kintsch, 1974 and Rumelhart, Lindsay, and Norman, 1972) avoid these difficulties by allowing many quantifiers to be represented primitively.

4. Similarly, if the object language contains logically simple names, they must each be dealt with. The appropriate clauses are of the form: a sequence *s* satisfies *Da* just in case *A* is a duck. Every combination of simple predicates and simple names must be similarly handled by a separate clause.

5. Davidson's own solution to this (Davidson, 1969) is to say that 'It is widely believed that the earth is round' has the joint structures of the two sentences.

The content of my next utterance is widely believed.

The earth is round.

In effect, the original sentence is banished from the object language.

6. These difficulties do not extend to adding quantifiers like 'most' or 'few'. Clauses for such quantifiers can be fairly straightforwardly added to the definition of satisfaction; cf. Wallace (1965).

7. On the basis of verification times, Carpenter (1973) theorizes that comprehension of counterfactual conditionals involves explicit negatives in the immediate representation of counterfactual clauses. She envisions nothing approaching the complexity of possible world semantics, however.

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