some of the bread
much of the bread
**soft of the bread*

much or none of the bread
**soft or none of the bread*

many or all linguists
**hungry or all linguists*

The analysis in [3] can be improved. But rather than pursue this topic we will be talking about *so* and *such* next time. We want to know whether *such* is not *so*, or not. Be prepared!

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Monotonicity Phenomena in Natural Language*

JACK HOEKSEMA

University of Pennsylvania

1. INTRODUCTION

This paper concerns itself with a rather elementary part of semantics, namely the study of relatively simple patterns of inference in natural language. This kind of study is as old as the Western linguistic tradition, since it has its origin in the work of Aristotle, and it is probably still the most robust part of modern formal semantics. Classical Aristotelian logic studied valid reasoning in natural language. At least in some quarters, the Fregean revolution in logic made natural language seem obsolete as a vehicle for logical reasoning. Only the last few decades has there been a return of interest in entailment relations between natural language sentences, especially under the influence of Montague and the Montague grammarians. However, the model-theoretic semantics that is used in Montague grammar does not provide a quick and easy tool for establishing what entails what, as the long and tedious derivations in standard textbooks show. However, in some recent work, the idea of returning to something much closer to classical logic appears to be emerging as an alternative to orthodox Montague grammar. In this paper, I discuss a set of inferential phenomena which I refer to here as 'monotonicity phenomena'. I will start with a discussion of logical inference, and then proceed with some more strictly linguistic applications of the notion, in particular its use for the description of negative polarity phenomena. My discussion of these matters will freely draw on the work of other linguists and logicians[1]. The presentation will be somewhat informal, focussing more on the main ideas than on technical details.

* This article was written in the winter of 1986 when the author was a visiting professor at the University of Washington in Seattle. An early version of this paper was presented in a talk at the University of Pennsylvania on February 27 1986. I am indebted to my teachers, Frans Zwarts and Johan van Benthem, whose work on monotonicity has been the main inspiration for this article.

[1] See also Sommers 1982, van Benthem 1986, Zwarts 1986, Ladusaw 1979 and the references cited there for further discussion.

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2. DICTUM DE OMNI ET NULLO

Let me begin by taking a look at some fairly typical inferences that one can make in natural language, such as the ones in (1):

(1) a. She gave him a rose
____
She gave him a flower

b. She kissed him.
____
She touched him

c. She has a German car
____
She has a European car

These inferences are valid modulo an extralogical assumption: that *rose* is a hyponym of *flower, kiss* of *touch* and *German* of *European*. Symbolically:

(2) rose < flower
kiss < touch
German < European

The hyponymy relation can be characterized in several ways that are ultimately equivalent. We could say that *rose* is a hyponym of *flower* because it is at least as informative, or, alternatively, because it denotes a subset of the set of flowers. The hyponymy relation reflects the structure of reality and for that reason I call it "extralogical". There is no logical necessity in the fact that roses are flowers or that Germany is in Europe. This does not mean, however, that this relation does not have clearly definable logical characteristics. It is a partial order since it is transitive and reflexive:

(3) Transitivity: $a < b,\ b < c \Rightarrow a < c$
Reflexivity $a < a$

Hyponymy is not a total ordering, since there are many pairs of expressions such that neither is a hyponym of the other, such as for instance *cat* and *dog*. Hyponymy, by the way, is a more basic notion than synonymy, since we can define the latter in terms of the former, but not vice versa:

(4) A = B (A is synomymous with B) iff A < B and B < A.

The relation between the hyponymy relation and entailment is not as straightforward as the examples under (1) might suggest. Let us, however, as a first approximation, consider the inference schema in (5), as a means to generalize over such inferences.

(5) *Dictum de Omni*
X A Y
A < B
____
X B Y

In other words, if we have a sentence in which an expression A occurs, and A is a hyponym of B, then the sentence in which we have replaced A by B follows. Notice that all the inferences in (1) are of this type. Instantiations of this schema, which is known in traditional Aristotelian logic as the *Dictum de Omni* are given in (6):

(6) a. Nina has a bulldog
bulldog < dog
____
Nina has a dog

b. Aldo kissed Nina
kiss < touch
____
Aldo touched Nina

c. A bulldog attacked Nina.
bulldog < dog
____
A dog attacked Nina

I want to point out here that Modus Ponens can be viewed as a special case of the more general inference schema in (5). To see this, note that the implication relation is simply the hyponymy relation holding between propositions. To say that p implies q is to say that p provides at least the same information as q. Alternatively, if p implies q, then the set of situations in which p is true is a subset of the set of situations in which q is true, just as a noun x is a hyponym of a noun y when x denotes a subset of y's denotation. Modus Ponens, then, is the special case of schema (5), where A and B are propositions and X and Y are zero:

(7) *Modus Ponens*
A
A < B
____
B

Another instance of the *Dictum de Omni* is what is known as Leibniz' Law, which states that one can replace, *salva veritate*, an element A for another element B in a linguistic expression if they are synonymous. This, of course, is just the special case of (5) where A = B. In short, the *Dictum de Omni* is a powerful inference scheme that accounts for a large set of valid inferences and can be seen as a generalization of Modus Ponens. However, it is all too clear that it allows too much. Consider what happens when A is under the scope of a negative expression, as is the case in the invalid patterns under (8).

(8) a. She did not give him a rose
rose < flower
———————————
She did not give him a flower

b. She never kissed him
kiss < touch
———————————
She never touched him

c. Nobody here has a German car
German < European
———————————
Nobody here has a European car

Notice that the problem is not restricted to sentences with items that are traditionally analyzed as negative, such as *not, never* and *nobody*, since the same problem arises with expressions that are not clearly negative, such as *every* and *before*:

(9) a. Every zebra is striped.
zebra < mammal
———————————
Every mammal is striped.

b. Before she kissed him, she brushed her teeth
kiss < touch
———————————
Before she touched him, she brushed her teeth

The proper formulation of the *Dictum de Omni* states that an expression A may be replaced by B only if A is a hyponym of B and furthermore, A is undistributed. The second requirement, which can be found in for instance Fred Sommers' book *The Logic of Natural Language*, must be carefully defined. To this end, we assign the value '+' to an expression x if the following holds for every y and z:

(10) $\dfrac{y < z}{xy < xz}$ or $\dfrac{y < z}{yx < yz}$

Likewise, assign the value '−' to x if the inverse holds:

(11) $\dfrac{y < z}{xz < xy}$ or $\dfrac{y < z}{zx < yx}$

The signs '+' and '−' that we assign in this way express the notion monotonicity. Curry (1963:103) defines an expression Q as *directly monotone* with respect to a relation R if X R Y implies QX R QY for all X,Y. Likewise, Q is *inversely monotone* with respect to R if X R Y implies QY R QX for all X,Y. The symbols '+' and '−', then, stand for, respectively, direct and inverse monotonicity with respect to the hyponymy relation. Monotonicity is a well-known notion in mathematics. A function f is said to be monotone increasing if x > y implies that f(x) > f(y). In more pedantic terms: f is directly monotone with respect to the greater-than relation. In yet other terms: f preserves the ordering on its domain. Examples of monotone increasing functions are:

(12) a. $f(x) = 2x$
b. $g(x) = x + 2$
c. $h(x) = x^3$

So for each of the above functions, the following inference scheme is valid:

(13) f(x) > a
y > x
———————
f(y) > a

Whether or not we may replace 'x' in the first premise by a larger number y depends on the monotonicity of the function. Now what about inferences involving the substitution of one function symbol for another, you may wonder. In (13), I made use of the natural ordering on the numbers. From this ordering, one can derive a partial ordering of numerical functions:

(14) f > g iff f(x) > g(x), for all x.

From this definition, the inference schema in (15) follows immediately:

(15)
$$\frac{f(x) > a \quad g > f}{g(x) > a}$$

This schema is closely related to (13) and has essentially the same structure. However, the possibility of substituting g for f is not restricted by the value of 'x', whereas the application of the substitution in (13) depends on whether the function is monotone increasing. In other words, we have a clear dichotomy between functions and their arguments.

This raises the question whether we find the same dichotomy in natural language. If so, this would give us interesting information about function-argument structure. It is often suggested, in particular by categorial grammarians, that natural languages have an operator-operand, or function-argument structure. Yet at the same time it has been rather difficult to settle on a particular function-argument division. Montague, for instance, in his paper PTQ, treats subjects as functors and verb phrases as their arguments, but elsewhere he analyzes verb phrases as functors selecting subject arguments. Transitive verbs are usually considered to be functor expressions with direct objects as their arguments. Sommers, and also Vennemann, in some of his papers, considers the direct object to be the operator and the transitive verb to be the argument. In addition, there are those who do not assume a fixed function-argument structure at all, like Geach and Lambek. Let us now see whether monotonicity has any bearing on the matter. If we apply the schemes in (10) and (11), it turns out that transitive verbs, with very few exceptions, receive the value '+', as the examples in (16) illustrate:

(16) a. a woman < a person
———
love a woman < love a person

b. marble < stone
———
buy marble < buy stone

c. Eliah < a prophet
———
follow Eliah < follow a prophet

d. a city in Spain < a city in Europe
———
know a city in Spain < know a city in Europe

The replacement of transitive verbs by more or less general verbs on the other hand clearly depends on the nature of the direct object. Take a look at the examples in (17):

(17) a. kiss < touch
———
kiss a woman < touch a woman

b. kiss < touch
———
touch no woman < kissed no woman

c. whisper < say
———
whisper more than three words < say more than three words

d. whisper < say
———
say less than three words < whisper less than three words

All of this is predicted if we assume with Sommers and Vennemann that direct objects are functors and transitive verbs their arguments, because substitution of arguments is sensitive to the logical properties of the functor, but not vice versa. However, their are exceptions, such as the verb *to lack*, which happens to be inversely monotone, as illustrated in (18):

(18) dinosaurs < reptiles
———
lack reptiles < lack dinosaurs

Compare this with the verb *have*:

(19) dinosaurs < reptiles
———
have dinosaurs < have reptiles

So generalization of the direct object may depend on the verb, and likewise, generalization of the verb may depend on the direct object. There is no completely clear-cut evidence for a functor-argument dichotomy from monotonicity facts.

Let's now consider what happens when we combine expressions. There is a simple set of rules that governs the monotonicity of complex expressions:

(20) + + = +
+ − = − + = −
− − = +

These rules may look familiar, because they are actually the same as the ones that govern multiplication of positive and negative numbers: the product of two positive numbers is positive, the product of a positive and a negative number is negative and the product of two negative numbers is positive again. This means that when an expression is under the scope of two inversely monotone operators, it behaves in the same way as when it is under the scope of a directly monotone operator. Examples that illustrate this are given in (21):

(21) a. He never lacked paper money
paper money < money
———————————
He never lacked money

b. At most three girls did not dance
dance < move
———————————
At most three girls did not move

This is not the whole story, however, since we also have to countenance the existence of nonmonotonous expressions. Compare the noun phrases *at least three boys* and *at most three boys* with the noun phrase *exactly three boys*. The latter does not allow inferences in any direction. For example, from the premiss that exactly three boys were skating, I may not draw the conclusion that exactly three boys were moving. Likewise, if exactly three boys are moving, it does not follow that exactly three boys are skating. Such nonmonotonous expressions, then, cut off the chain of inference. There are two types of nonmonotonous expressions, those that block any kind of substitution, also known as opaque or intensional operators and those that still allow substitution of equivalent expressions. Cf.:

(22) a. Pete believes he is a spider
black widow < spider < arachnid
———————————
Pete believes he is a black widow/arachnid

b. Paul is a good father
grandfather < father < man
———————————
Paul is a good grandfather/man

(23) a. Exactly five students brought nuts
hazelnuts < nuts < food
———————————
Exactly five students brought hazelnuts/food

b. The man left
king < man < mammal
———————————
The king/mammal left

The examples in (23) still allow substitution by extensional equivalents, whereas the ones in (22) don't. Rules that describe the results of combining nonmonotonous expressions with other kinds of expressions are given in (24)[2]:

(24)
n n = n
n + = n
n − = n
− n = n
+ n = n

or, shorter:

(25) x n = n x = n (where x = n, +, −)

The upshot of these equations is that a combination of monotone operators behaves as a single monotone operator, but as soon as one nonmonotone operator is added, the monotonicity behavior disappears. To determine the direction of monotonicity in a sequence of monotone operators, it is sufficient to count the number of inversely monotone expressions. If this number is odd, then the sequence counts as inversely monotone, and if it is even, it is directly monotone. We can now return to the definition of the notion 'distribution' to which I referred earlier on. An expression is undistributed if and only if it occurs under the scope of an even number of inversely monotone expressions and no nonmonotone expressions. An expression is distributed if and only if it occurs under the scope of an odd number of inversely monotone and no nonmonotone operators. This is an improvement on

[2] There is an additional complication if complex functors are considered, such as *no student* or *every bachelor*. The monotonicity behavior of such expressions is not in general computable from that of the parts. For instance, whereas both *no* and *every* are '−', *no student* is '−', but *every student* is '+'. One way out of this problem is suggested by Zwarts (1983), who analyzes determiners as binary operators, taking two predicates (typically a common noun and a verb) as its arguments. *Every* can then be treated as '−' in one and '+' in the other argument, whereas *no* is '−' in both argument positions. An old result by Curry guarantees that the combination of a complex unary functor and its argument can always be analyzed as that of a single n-ary functor with n arguments, and so it is possible to characterize the monotonicity properties of any given expression solely in terms of the +/− marking of the its primitive parts.

traditional characterizations of distribution, which simply say that a term is distributed in a proposition if the proposition is about the entire extension of the term. The present definition is more general, because it extends to expressions that are not terms, such as subordinate clauses. Furthermore, it is hard to see how the traditional notion of distribution can be extended to cases like *at most 3 dogs were hungry*, in which the terms *dogs* and *hungry* can be replaced by more specific ones. Surely such statements are neither about all dogs, nor about all hungry individuals. The *Dictum de Omni*, now properly restricted to undistributed expressions, follows directly from the definition of monotonicity. For distributed expressions, the converse of the *Dictum* holds, viz. the following principle:

(26) *Dictum de Nullo*
X A Y
B < A
―――――
X B Y (where A is distributed)

Examples of this inference schema are given in (27) below:

(27) a. Nobody moved
dance < move
―――――
Nobody danced
b. We never touched
kiss < touch
―――――
We never kissed
c. All philosophers are mortal
Hegelians < philosophers
―――――
All Hegelians are mortal

3. APPLICATION TO NEGATIVE POLARITY ITEMS

Monotonicity is not just an interesting notion in theories of inference. Recently, it has been stressed by several linguists that inverse monotonicity is the key to understanding negative polarity items (cf. Fauconnier 1979, Ladusaw 1979, Zwarts 1986). In particular, it has been argued recently that negative polarity items can be characterized as those expressions that may only occur under the scope of an inversely monotone operator. Examples of such items are given in (28):

(28) a. budge an inch/lift a finger/care a hoot
b. anything (whatsoever)
c. anymore
d. all that
e. ever
f. at all

Consider once more the difference in monotonicity between *at least three women* and *at most three women*. Since the latter is inversely monotone, but not the former, we predict that only the latter may trigger, so to speak, a negative polarity item. This prediction is correct, as Ladusaw (1979) has pointed out:

(29) a. At most three women have *ever* loved him.
b. ?At least three women have *ever* loved him.

Likewise, Ladusaw has noted that the determiner *all* is inversely monotone, but the noun phrase *all boys* is directly monotone. So we expect to find negative polarity items in the scope of *all*, but not in the scope of *all boys*. This is correct, as examples such as (29c, d) indicate:

(29) c. All boys who budged an inch were rejected.
d. *All boys who were rejected budged an inch.

Similar monotonicity differences give rise to the differences in acceptability in (30):

(30) a. None of the rivals said *anything whatsoever*.
b. *Some of the rivals said *anything whatsoever*.
c. I didn't think it was *all that* dangerous.
d. *I thought it was *all that* dangerous.
e. Never did I see *anyone* so desolate.
f. *That moment I saw *anyone* so desolate.
g. If he speaks *at all*, be sure to write it down.
h. *If he speaks, be sure to write it down *at all*.

The main result of Ladusaw's work on negative polarity items is that it shows how the notion of an inversely monotone expression can give a precise semantic characterization of the triggers of negative polarity items.

Let me make here a few remarks on the relation of monotonicity to definiteness. A definite NP refers to an individual or set of individuals

whose identity can be established on the basis of the preceding discourse or the nonlinguistic context. It has sometimes been suggested, among others by Chomsky, that definite descriptions such as *the father of Alice* are universal quantifiers. So, in other words, a sentence like *the father of Alice is a gardener* should be read as *every father of Alice is a gardener*. If this is indeed correct, then we would predict to find the same inferential pattern that we associate with universal quantifiers. In particular, we predict that a term in construction with a definite article may be replaced by a more specific term. However it seems that we get strange results if we allow this. Does it follow from the statement that the dog is sick that the bulldog is sick? Well, maybe if the dog in question is a bulldog. In general, such a conclusion seems unwarranted. Are we then on the wrong track to assume universal force for definite descriptions? Not necessarily. On the account of definite articles given by Barwise and Cooper (1981), the NP *the dog* is interpreted as *every dog* just in case there is exactly one dog and is undefined otherwise. According to this interpretation, the definite article *the* is not inversely monotone. For instance, if it is true that the dog is sick, then the statement that the bulldog is sick is either true (just in case the dog in question is a bulldog), or undefined (in case the dog isn't a bulldog). So it seems that we can no longer safely conclude from the sickness of the dog the sickness of a bulldog. The same is true in Montague's (1973) "Russellian" treatment of *the*, according to which *the dog is sick* is false whenever there is no unique dog in the domain of discourse. It is predicted, then, that negative polarity items are not licensed by definite descriptions:

(31) *The sailor who had ever visited this island was killed by its inhabitants.

(32) *The answers that were ever given to this question are unsatisfactory.

As we see from (31) and (32), this prediction appears to be correct.

A similar account might be proposed for the anomalous behaviour to the universal quantifier *each* (discussed in Seuren 1985). Unlike *every* and *all*, *each* does not trigger negative polarity items in relative clauses:

(33) a. All sailors who have ever seen the island wanted to stay there.
b. Everyone who has ever studied this problem, went bonkers.
c. *Each student who has ever passed his test, died soon thereafter.

The source of this difference seems to lie in the definite nature of *each*. Like the definite determiners, it is particularly appropriate when used to refer to "given" material. For instance, when entering a house, you can shout "Where is everybody?", but hardly "Where is each one?". If this is on the right track, then it seems that the failure of *each* to trigger negative polarity items simply follows from its definite character.

Now consider what happens when two inversely monotone expressions cancel out each other's monotonicity. According to Ladusaw, this would not have an effect on negative polarity items, because they only require the existence of a trigger. As soon as such a trigger is present, it does not matter whether the polarity item itself is distributed or not. This seems to be a correct observation, cf. the examples in (34):

(34) a. If he knows anything about logic, he will know Modus Ponens.
b. If he doesn't know anything about logic, he will not know Modus Ponens.
c. If he lifts a finger, fire him.
d. If he doesn't lift a finger, fire him.

However, the following sentences appear to be counterexamples:

(35) a. All students who know anything about logic should know Modus Ponens.
b. ?Not all students who know anything about logic know Modus Ponens.

If the lesser acceptability of example (35b) is to be attributed to the fact that the two inversely monotone operators *not* and *all* cancel one another out, then the question arises why the addition of negation in the examples in (32) does not have the same effect on the acceptability of the polarity items involved. The explanation that I would like to advance here is, that the correct structure of *not all students* isn't *[not [all students]* but rather *[[not all] students]*, with a complex determiner *not all*. This complex determiner is directly monotone, by virtue of its being the negation of the inversely monotone determiner *all*. Consequently it does not license negative polarity items within its scope.

There is independent evidence for the correctness of this particular analysis. Note that *not* does not combine with every determiner. Cf. the list below:

(36) a. not one
b. not a (single)
c. not a few
d. not many
e. not every
f. not more than ten
g. not that many
h. not a lot of

(37) a. *not several
b. *not three
c. *not each
d. *not most
e. *not a number of
f. *not no
g. *not the
h. *not that

I have not been able to find a semantic generalization that sets the determiners in (36) apart from the determiners in (37). If it is a matter of lexical selection, as I suspect it is, then it makes sense to analyze *not* as an expression that directly combines with a determiner, instead of a noun phrase. Furthermore, if *not* selects a determiner, rather than a noun phrase, it is correctly predicted that it does not combine with a lexical NP, such as *John*[3].

The same explanation can be given for the oddness of sentences such as:

(38) ?Not only John has ever set foot on this island.

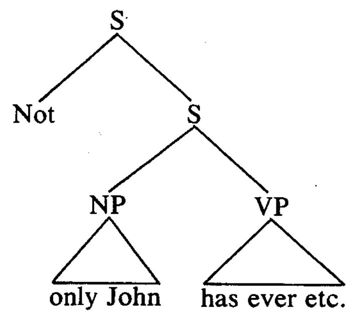
In spite of the two triggers *not* and *only*, the polarity item *ever* does not seem to be in its proper place. Compare this with similar sentences such as:

(39) a. Not one sailor has ever landed on this island.
b. Only her husband was ever allowed to see her face.

The reason is, that the predicate in (38), *has ever set foot on this island*, is combined with the complex noun phrase *not only John*. This complex noun phrase contains two inversely monotone expressions, which results in a directly monotone expression. If the structure of sentence (38) were instead as indicated in (40), we would predict the acceptability of polarity items in the verb phrase:

[3] The fact that *not John* can occur in constructions with contrastive negation (e.g. *not John left, but Sam*) does not militate against my point, since such constructions must be dealt with separately anyway (cf. Jacobs 1982 for a discussion of related phenomena in German).

(40)



Indeed, if we change (38) in such a way that the negation is separated from the subject, the result becomes much more acceptable:

(41) It is not the case that only John has ever set foot on this island.

Another interesting illustration for the claim that negative polarity items must be under the scope of an inversely monotone expression, but do not have to occur in a distributed position, is provided by propositional attitude verbs and similar opaque operators:

(42) a. Nobody thinks that he will ever finish his degree.
b. Never assume that anybody would care a fig for him.

Clearly, elements in the scope of such verbs are not in a distributed position, since, as we have seen, the nonmonotone nature of opaque opertors destroys any monotonicity patterns that might exist.

To conclude: I have defined and illustrated the notions of direct and inverse monotonicity and indicated how they play a role in the study of inference patterns. Then I explained how one of these notions, namely inverse monotonicity, makes it possible to state a generalization about the distribution of negative polarity items. What I find particularly interesting is the fact that all of this has been developed without any direct reference to modeltheoretic or other types of semantics. To be sure, this does not mean that we do not need semantics. For instance, we can describe the different monotonicity properties of *at most three* and *at least three* without recourse to their interpretation, but only a semantic theory of determiners is going to predict this difference. Monotonicity, then, is essentially a semantic phenomenon, to be understood fully only in semantic terms, but it allows a theory of inference which is much more direct, and one would imagine, much

more useful for computational applications, than, say, standard Montegovian theories of inference.

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The Lexical Nature of Quantifiers in Japanese* Part II

YASUKUNI TAKANO

University of Washington

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0. INTRODUCTION

In Takano [15], it was argued that the (a) examples and (b) or (c) examples below should not be related by transformations or other rules having the effect of floating or moving quantifiers.

(1) a. *Sitinin-no* samurai-ga ki-ta.
7 GEN SUBJ come-pst
'*Seven* samurai came.'
b. Samurai-ga *sitinin* ki-ta.

(2) a. Yoojinboo-ga *sitinin-no* samurai-o tukamae-ta.
Bodyguard-SUBJ 7 GEN OBJ capture-pst
'The bodyguard captured *seven* samurai.'
b. Yoojinboo-ga samurai-o *sitinin* tukamae-ta.

(3) a. *Sitinin-no* samurai-ga yama-de kin-o mituke-ta.
7 GEN SUBJ mountain-in gold-OBJ find-pst
'*Seven* samurai found (some) gold in the mountain.'
b. Samurai-ga *sitinin* yama-de kin-o mituke-ta.
c. Samurai-ga yama-de *sitinin* kin-o mituke-ta.

(4) a. Yoojinboo-ga *sitinin-no* samurai-o
Bodyguard-SUBJ 7 GEN OBJ
sudeni korosite-simat-ta.
already kill-perf-pst
'The bodyguard has already killed *seven* samurai.'
b. Yoojinboo-ga samurai-o *sitinin* sudeni korosite-simat-ta.
c. Yoojinboo-ga samurai-o sudeni *sitinin* korosite-simat-ta.

According to the traditional transformational approach, cf. Okutsu [11, 12], Shibatani [13, 14], Kamio [3], Kuno [6], and Haig [1], these

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