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Natural Units of Representation Interact during Sentence Comprehension

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Subjects read aloud the verb IS or ARE that was projected to interrupt a spoken sentence: immediately preceding the projected word, the sentence contained a "verb + ing noun" sequence, which was either a gerund ("raking leaves"), an adjectival phrase ("diving submarines") or ambiguous ("growing flowers"). The experiment investigated the effect on word-reading time of various independent variables in the preceding context clause that biased the subject to expect either a gerund or adjectival construction: the operational measure of the effectiveness of a context was the difference in reading time between a word consistent with the bias and a word inconsistent with the bias. The strongest effects occurred when the "verb + ing noun" phrase was ambiguous and (1) the plural/singular dimension in the preceding context clause was morphologically explicit, (2) the context clause was introduced by THOUGH (as opposed to IF, or being a main clause), (3) there was an explicit form of BE in the context clause, (4) the biased interpretation from the context clause was the gerund. These effects and others support a structurally differentiated model of comprehension in which listeners link representations at distinct levels of representation expressed in the units that are most natural at that level (e.g., propositions at the semantic level, words and word-groupings at the syntactic level).

Recent research has concerned the extent to which previous context influences the on-line processing of sentences. What is at issue in this article is whether and how contextual information is used directly in the assignment of syntactic structures that group adjacent phrases into potential units of meaning.

We contrast two interactive models of the relation between context and comprehensive processes. The undifferentiated model assumes that all levels of contextual information can interact during processing (e.g., Tyler & Marslen-Wilson, 1977). On a particular differentiated model, a natural unit (NU) model, there are natural units at each level of analysis that constrain the interrelation between levels. For example, the semantic and syntactic levels interact most fully at points that correspond simultaneously to propositions and groups of words and morphemes. Listeners use an accumulated set of formulaic comprehension strategies which relate natural configurations at one level with natural configurations at another level. Such strategies can be visualized as Janus-like structures which link a template at one level to a template at another. By hypothesis, they operate passively so that levels interact most naturally at points that correspond to complete units. For example, if a syntactic

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sequence forms a potential perceptual unit, at that point contextual information can be integrated with its interpretation. If a sequence is syntactically ambiguous, then context can be utilized only at the point when one of its interpretations comprises a possible perceptual unit; at such a point that interpretation can be integrated with the context and rejected if inappropriate. This theoretical framework predicts that levels of processing are relatively autonomous except at points that correspond to natural units at more than one level.

On the strongest version of such a model, both structures of a syntactic ambiguity are assigned regardless of their context (Bever, Garrett, & Hurtig, 1973; Hurtig, 1978). In support of this, Bever et al. (1973) demonstrated that an incomplete clause fragment takes longer to complete when it contains an ambiguous phrase than when it contains an unambiguous phrase; however, when the critical phrase occurs in a complete clause, sentence completion times do not depend on the ambiguity of the phrase. Hurtig (1978) demonstrated that these effects of ambiguity on fragment completion time are maintained even after a disambiguating context. Both Bever et al. (1973) and Hurtig (1978) argued that alternate hypothetical meanings of a meaning unit (defined as the surface structure clause) are developed separately during the unit, but are discarded at the end of the unit, when one meaning is chosen. This theory assumed "on-line" processing of alternate meaning/structure hypotheses during a clause and closure around one hypothesis by the end of the clause. It was subsequently demonstrated that the extent of the closure itself depends on the kind of sequence and its relation to the rest of the sentence (Bever, 1975; Bever & Townsend, 1979; Carroll, 1978; Carroll & Bever, 1976; Tanenhaus & Carroll, 1975; Townsend, in press; Townsend & Bever, 1978).

Tyler and Marslen-Wilson (1977) investigated the on-line utilization of context in syntactic processing. They presented subjects with initial unambiguous clauses, followed by an ambiguous phrase of the form "verb + ing noun" which could either be an adjectival or a gerund (e.g., (1)).

(1) . . . growing flowers. . . .

The preceding context clause was consistent with either the adjectival interpretation (as in (2)) or the gerund (as in (3)).

(2) Although dead ones are ugly. . . .

(3) Although looking after plants is easy. . . .

Immediately after the critical phrase, a slide appeared, which the subject was to read aloud: the slide contained either IS or ARE. Reading times for the verb were faster when the context clause was consistent with the corresponding interpretation of the critical sequence. Tyler and Marslen-Wilson concluded that "semantic context" makes a structural ambiguity functionally unambiguous, even before the completion of the proposition that contains the ambiguity. Furthermore, they found that the effect of the structural properties of unambiguous adjectival (4) and gerund (5) phrases on verb-reading times was the same as that of the "semantic context" preceding ambiguous phrases.

(4) . . . living flowers. . . .

(5) . . . watering flowers. . . .

They argued that this shows that across-clause context is as effective at disambiguation as within-clause context, and hence that contextual and syntactic information are treated as functionally equivalent by the sentence processor.

Tyler and Marslen-Wilson's (1977) results appear to contradict the NU model. However, several aspects of their experiment require special interpretation in light of the NU model. First, the gerund construction has been shown to act as a potential functional clause (Tanenhaus & Carroll, 1975). The extent to which a potential proposition corresponds to the canonical subject–verb–object order increases its salience as a perceptual unit. For example, Tanenhaus and Carroll (1975) (Carroll, 1978) showed that there is more closure around an adjective phrase when the adjective follows the noun than when it precedes

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it. Carey, Mehler, and Bever (1970) also demonstrated that when a sentence corresponded to the canonical order (6) it was more quickly interpreted than when it did not (7).

(6) They are fixing benches.

(7) They are rotting benches.

Based on these considerations, the NU model predicts that Tyler and Marslen-Wilson's results were primarily due to contexts which were consistent with the gerund interpretation.

Second, the kind of relation a sequence bears to the rest of the sentence influences the extent to which it is immediately treated as a separate perceptual unit (Townsend & Bever, 1978). For example, a causal subordinate clause (8) is more independent than an adversative one (9).

(8) If dead ones are ugly. . . .

(9) Although dead ones are ugly. . . .

This follows from the fact that the meaning of a causal clause is not strongly affected by whatever follows. However, the meaning of an adversative clause is strongly determined by the following clause (Dakin, 1970). Townsend and Bever (1978) (Bever & Townsend, 1979; Townsend, in press) confirmed the behavioral reflexes of this difference by showing that while the meaning of a causal clause is relatively more accessible as it is heard, the literal sequence of an adversative clause is more accessible. That is, a causal clause is immediately recoded semantically, while an adversative clause is held in more literal form to be integrated with the following sequence. This predicts that the superficial form of adversative contexts has more effect than causal contexts on later processing. Analysis of Tyler and Marslen-Wilson's results demonstrates a numerically stronger verb reading time effect for adversative contexts than for other contexts.[1]

There are also several notable properties of Tyler and Marslen-Wilson's stimuli which might account for the phenomena, quite independently of linguistic effects of context. The disambiguating contexts characteristically included a morphologically explicit plural or singular verb, often a form of the verb BE itself, as in (2) and (3). Furthermore, the contexts often contained a morphologically marked singular or plural initial noun phrase that agreed in number with the intended effect of the context. In some cases, as in (3), there was an explicit model of the same construction as the intended disambiguation of the critical phrase. All 28 disambiguation context pairs had clear verb or number cues in one direction or the other—of these, 23 pairs were consonant with the intended disambiguation (see Table 1). Of course, the fact that verb and number information systematically co-occurred in the context clauses does not in itself prove that the critical phrases were not disambiguated on-line. The experimental measure, however, of latency to read IS or ARE aloud might be susceptible to lexical cueing on the basis of the previous verb and number, quite independent of its role in disambiguating syntactic structures. To put it operationally, the question is whether the contexts in (10) and (11) would influence reading time for IS versus ARE, given the absence of any critical ambiguous phrase.

(10) If they are there, when. . . (ARE the Jones' coming?)

(11) If it is there, when. . . (IS Jones coming?)

The results of Tyler and Marslen-Wilson (1977) were sufficiently suggestive on these issues to motivate a careful investigation of the phenomena they report. We designed an experiment similar to theirs, in our case systematically varying morphologically explicit number, context conjunction, and context verb, as well as nonmorphological bias. The undifferentiated model predicts that the same effects occur across all these variables.

To understand the predictions of the NU model, it is necessary to spell out its operations in some detail. For present purposes,

[1] The mean effect was 70 milliseconds for adversative contexts and 34 milliseconds for causal contexts. Tyler and Marslen-Wilson kindly provided us this numerical information.

TABLE 1
SUMMARY OF TYLER AND MARSLEN-WILSON'S (1977) MATERIALS

A. Total number of numerically distinct cues that agree vs. disagree with the direction of the semantic bias of the context

Semantic bias	Cue agrees	Cue disagrees
Singular	35	6
Plural	42	3

B. Number of contexts in which the first numerically distinct cue agrees with semantic bias, depending on locus of first numerically distinct cue

Semantic bias	First NP	Verb	Second NP	Total
Singular (n = 28)	12	2	10	24
Plural (n = 28)	19	1	5	25

C. Number of contexts containing an unambiguous "V–ing N" phrase

Semantic bias	Gerund phrase	Adjectival phrase
Singular	4	0
Plural	0	2

we assume that there are rapid mechanisms which assign potential lexical class information to each word. We are not primarily concerned with such recognition here, although it should be noted that it too may be influenced by contextually-determined semantic fields. We should also stipulate that available morphological information from context can always influence ongoing structural processing, as in priming a particular phonological sequence. Our main concern here is how words are related to each other in larger units of structure and associated meaning, and with the proposal that it is primarily those units that are related to the meaning of the context.

During listening a set of perceptual strategies constantly relates the word sequences to potential local structures. This builds up a number of potential syntactic organizations for each subsequence. When such an organization corresponds to a propositional unit it is thereby assigned a semantic interpretation consistent with the meaning of the lexical items and the structural information assigned by the perceptual strategy. At that point it is available to integrate with previous context.

Various strategies serve the function of mapping words onto sematic roles (Bever, 1970; Fodor, Bever, & Garrett, 1974). There are a number of distinct models of what cues can be used to impose structural and semantic organization on the speech sequence (e.g., Bobrow & Fraser, 1969; Frazier & Fodor, 1978; Kaplan, 1972; Kimball, 1973; Kuno & Oettinger, 1963; Thorne, Bratley, & Dewar, 1968; Wanner & Maratsos, 1977; Winograd, 1972). These models give special status to a small set of syntactic markers, the "function morphemes." In this article we are not concerned with the validity of any particular model of such perceptual strategies, but it is useful to consider how a sequence of such operations would apply to an ambiguous sequence like (1). The word sequence is assigned a possible structure in terms of lexical class and function morphemes:

(12) G R O W I N G F L O W E R S
((V + ING) (N + PL))

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This sequence can be organized internally according to several strategies. The two that are relevant are (named for convenience):[2]

(13) ADJ: ## V+ING NOUN+PL
⟨==⟩
NP – PL(ADJ(ACTION)N(ACTOR))
NP – PL(ADJ"FOR"ACTION)-N(ACTOR))

(14) GER: ## V + ING NOUN + PL
⟨==⟩
NP – SG(S(ACTION)N(OBJECT))

Although both organizations involve major propositional relations, and both present the verb, there are at least two reasons why the gerund organization serves as a relatively complete perceptual unit compared with the adjectival organization: the only relation the gerund could have to the rest of the sentence requires that it be treated as a proposition (i.e., it is the entire proposition that bears the grammatical relation to the main verb); unlike the adjectival organization it presents a subpart of the canonical sentence order. As the GER strategy applies it automatically interprets the sequence into a relatively natural semantic unit. At this point, the sequence can be related to the previous context. Either strategy can also be a term in a larger strategy that predicts aspects of subsequent phrases, as below. (This represents the prediction that a noun phrase at the beginning of a sentence will be followed by an inflected verb with the same number of which it is the actor.)

(15) ##NP + (number=X) ⟨==⟩
##NP + (number=X)subject. . .
VP(number=X)

If the interpretation is inappropriate to the context, or to the immediately following word, alternate structural organizations (e.g., that simultaneously assigned by ADJ) are continued as potentially correct. If the sequence is unambiguous, as in (4) or (5), more than one potential structure is still assigned until a natural perceptual unit is reached. At this point, the GER assignment to (4) is dropped, because the lexical interpretation of the verb does not allow a direct object. (By hypothesis, however, the attempted GER interpretation will be related to the previous context, even though the structure may be invalid for local lexical reasons.)

This model makes several qualitative predictions for a verb reading time experiment like that of Tyler and Marslen-Wilson in which morphological cues, nonmorphological cues, context verb, context conjunction, and target-verb number are controlled variables. For ambiguous stimuli there are two effects of context on the expected verb: an effect via semantic interpretation, and an effect via morphologically explicit number. Because adversative clause information is less recoded than causal clause information, the model predicts that the effect of morphologically explicit cues will be greater for THOUGH than IF contexts, and that this in turn will be greater for contexts with a form of BE in them. Because contextual integration occurs primarily at the ends of natural semantic units, the model predicts that all effects of context will be greater when the expected interpretation is the gerund than when it is the adjectival construction.

For unambiguous cases, reading time should be primarily affected by the local

[2] Like Tyler and Marslen-Wilson, we used two subtypes of adjectival configurations, one in which the V + ing interpretation as an adjective is derived from the progressive tense, for example, "growing flowers" (ambiguous), "travelling salesmen" (unambiguous); in the other constructions, the V + ing interpretation is characteristically a deverbal noun, as in "cutting boards" (ambiguous) and "dancing classes" (unambiguous). On either interpretation the ADJ construction is a weaker propositional unit than the gerund. In our materials, 42% of the cases potentially had the deverbal noun interpretation in both the ambiguous and unambiguous sets.

unambiguous structure. The local structural effects should be equally strong for gerund and adjectival constructions, since the superiority of the gerund as a semantic unit is relevant only to contextual integration. The effect of local unambiguous structure should be relatively large for THOUGH contexts, which depend on local unambiguous structure in the final clause more than do IF contexts. Conversely, the bias from a preceding IF context should have a larger effect than that from a THOUGH context, primarily when the biased interpretation is the gerund. This follows from the fact that the semantic integration with the IF context can occur immediately, while the THOUGH context itself is not fully interpreted until the following clause information is available. The results for main clause contexts should be intermediate—on the one hand, like a causal subordinate clause, a main clause can be analyzed independently of what follows; on the other hand, because it is a main clause it may also be closed off from the following clause, and exhibit certain effects like an initial adversative clause. Finally, unambiguous phrases in initial clauses should exert the greatest influence on verb reading time in initial IF clauses, since they are immediately recoded into a contextually-relevant form; these effects should be smaller for initial THOUGH and main clauses because they (for different reasons) are not used to predict a context.

The most important result of Tyler and Marslen-Wilson (1977) was their failure to find an effect of local within-clause structural bias that differed from that of semantic across-clause bias. While there may be no overall differences, our model predicts that the across-clause effects will be more pronounced for the gerund bias, but the within-clause effects will be equal between the two biases.

METHOD

The basic technique and design are extensions of Tyler and Marslen-Wilson (1977). Subjects listened to a sentence fragment, then read aloud as quickly as possible a word that appeared on a screen. The critical cases were instances of IS or ARE immediately following a spoken "verb + ing noun" sequence. In our materials we controlled for the presence of morphologically marked number in the preceding context, the kind of clause relation between the context and the critical phrase, and other variables, as described below.

Materials

There were 24 ambiguous "verb – ing noun" phrases. For each ambiguous phrase, two nonmorphologically biasing context clauses were constructed, so that the phrase was biased toward either the gerund or adjectival interpretation. For 12 of the ambiguous phrases, the context clauses contained either IS or ARE as part of the main verb, and for the other 12 phrases, the context clauses contained a present tense main verb without a form of BE. Each context clause contained a completely specified set of SVO relations; in particular, there were no pronouns with unspecified referents. The context clauses contained an average of 8 words, both for contexts containing a form of BE and for contexts containing some other verb. The two nonmorphologically biasing context clauses were slightly modified by changing the number, that is, singular or plural, attached to the subject noun and the verb, thus generating two verb number biasing context clauses for each of the nonmorphologically biasing context clauses. Examples of the four major types of contexts associated with each ambiguous phrase appear in Table 2. The context clauses and phrases were then paired with IF or THOUGH as sentence introducers, or with SO introducing the phrase, thereby generating twelve contexts for each phrase.

The strength of the nonmorphological bias of the context clauses was evaluated by a pretest. The twelve contexts for each phrase were arranged into 12 booklets, together with the contexts for unambiguous phrases described below and 4 other sets of

TABLE 2
SAMPLE AMBIGUOUS FRAGMENTS

I. Singular morphological bias
  A. Context clause contains IS
    1. Singular nonmorphological bias: If the pilot is required to attend flight school, landing planes . . .
    2. Plural nonmorphological bias: If the airline's ground crew is on the runway, landing planes . . .
  B. Context clause does not contain IS/ARE
    1. Singular nonmorphological bias: If the pit crew works very efficiently, racing cars . . .
    2. Plural nonmorphological bias: If a young boy enjoys intense competition, racing cars . . .
II. Plural morphological bias
  A. Context clause contains ARE
    1. Singular nonmorphological bias: If pilots are required to attend flight school, landing planes . . .
    2. Plural nonmorphological bias: If ground crews are very often on the runway, landing planes . . .
  B. Context clause does not contain IS/ARE
    1. Singular nonmorphological bias: If the pit crews work very efficiently, racing cars . . .
    2. Plural nonmorphological bias: If young boys enjoy the intense competition, racing cars . . .

context-ambiguous phrase pairs which were subsequently discarded. Forty-eight subjects were asked to continue the fragments in order to make a complete sentence and to rate the naturalness of the fragment. For the 24 ambiguous fragments retained for the experiment, continuations of verbs with the correct number, as defined by the nonmorphologically biasing context, occurred at a rate of 79.9% (Table 3). The percentage of continuations of verbs with the nonmorphologically correct number did not vary across morphological or nonmorphological bias, and there was no interaction, all Fs < 1.

There were 24 unambiguous "verb – ing noun" phrases ending final clause fragments, 12 with the gerund interpretation and 12 with the adjectival interpretation (cf. footnote 2). The construction of context clauses for these fragments was identical to that for the ambiguous fragments, with the exceptions that there no "nonmorphologically biasing contexts" and that eight of the 24 phrases had contexts with a form of BE as part of the main verb (see Table 4 for examples). For each unambiguous phrase there were six contexts defined by number on the verb in the initial clause and conjunction.

There were 12 additional unambiguous "verb – ing noun" phrases, 6 each with the gerund and adjectival interpretation (see Table 4). These were used as initial clause fragments, appearing with either IF, THOUGH, or no conjunction.

There were 48 filler fragments; 24 were initial clause fragments and 24 were final clause fragments. The initial clause fillers did not contain a main verb but ended with either an unambiguous gerund noun phrase or an unambiguous adjectival noun phrase (12 of each); these noun phrases were not the main subject of the clause. The 24 final clause fillers all contained a gerund or adjectival phrase (12 of each) in the initial clause; these fragments ended with a simple singular or plural subject. The three conjunctions each occurred 8 times in each type of filler fragment. An additional 18 fragments, representing a mixture of ambiguous fragments, unambiguous final clause fragments, unambiguous initial clause fragments, and final clause filler

TABLE 3
PERCENTAGE OF VERBS PRODUCED THAT ARE CONSISTENT IN NUMBER WITH NONMORPHOLOGICAL BIAS

Morphological bias	Nonmorphological bias		
	Singular	Plural	Overall
Singular	80.5	78.5	80.1
Plural	84.8	78.8	79.5
Overall	80.9	78.7	79.9

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TABLE 4
SAMPLE UNAMBIGUOUS FRAGMENTS

	Final clauses
I.	Singular morphological bias
	1. Gerund structure: If the boxer wants to avoid unnecessary injuries, dodging punches . . .
	2. Adjectival structure: If the instructor gets all the students involved, dancing classes . . .
II.	Plural morphological bias
	1. Gerund structure: If the boxers want to avoid unnecessary injuries, dodging punches . . .
	2. Adjectival structure: If the instructors get all the students involved, dancing classes . . .
	Initial clauses
1.	Gerund structure: If riding subways . . .
2.	Adjectival structure: If diving submarines . . .

fragments, were constructed for practice trials.

The various fragments were arranged randomly into 12 lists of 126 fragments, except that across the four blocks of 27 test and filler fragments each fragment type occurred an equal number of times. The fragments were recorded in monotone voice by an experienced male reader on one channel of tape, and on the other channel a timing tone was placed so that it coincided with the onset of the last word of each fragment.

Two lists of target words were prepared. The targets for ambiguous fragments were either IS or ARE. The targets for other types of fragments were a mixture of IS and ARE (four of each for unambiguous final clause fragments), but predominantly some other verb. The two lists of targets differed in the number attached to target verbs for ambiguous final clause fragments, unambiguous final clause fragments, and unambiguous initial clause fragments.

Procedure

The instructions to the subjects were to listen to sentence fragments, read aloud as quickly as possible the word that appeared by slide when the fragment ended, and then indicate whether or not the word was an appropriate or inappropriate continuation. The sentence fragments were presented binaurally through headphones and were preceded by a warning tone one second before the onset of the fragment. The timing tone, which was not heard by the subject, opened a shutter which allowed the projection of the word onto a screen in front of the subject, and simultaneously started a millisecond timer, which was stopped by the subject's vocal response.

Subjects

Twenty-four right-handed male native speakers of English at Columbia University served as subjects as part of a course requirement. Pairs of subjects were assigned to each of the twelve lists of fragments, one subject in each pair to each of the two target lists.

RESULTS

The mean overall response time was 709 milliseconds. (Less than 4% of the data were lost to timing errors, and 0.5% of response times greater than 2000 milliseconds were excluded.) The response time data were converted to log scores and differences were examined by analysis of variance.

1. Ambiguous Sequences in Final Clauses

Analysis of variance of the log scores of response times for ambiguous trials using nonmorphological bias, morphological bias, conjunction, target number, and initial clause verb as variables showed the following:

(a) Morphologically marked number had a significant bias effect in the expected direction (Table 5), $F1\ (1,22) = 7.23$, $p <$

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TABLE 5
MEAN-RESPONSE TIMES FOR AMBIGUOUS FRAGMENTS DEPENDING ON MORPHOLOGICAL AND NONMORPHOLOGICAL BIAS

	Singular target	Plural target	Bias effect
	Morphological bias		
Singular bias	641	733	92
Plural bias	653	653	0
	Nonmorphological bias		
Singular bias	623	710	87
Plural bias	658	666	−8

.025, $F2$ (1,22) = 2.25, $p > .10$. There was no overall effect of nonmorphological bias, $F1$ (1,22) = 2.81, $p > .10$, $F2$ (1,22) = 3.71, $p > .05$.

(b) All biasing effects of context clauses were stronger when the biased interpretation was singular. The morphological effect was primarily due to a significant target effect for singular morphological biases, $F1$ (1,22) = 14.6, $p < .001$, $F2$ (1,22) = 5.81, $p < .025$; there was no effect for plural morphological biases, $F1$ and $F2 < 1$. There was an independent effect of nonmorphological bias when the bias was singular, $F1$ (1,22) = 12.5, $p < .01$, $F2$ (1,22) = 16.6, $p < .001$; the bias effect for plural nonmorphological biases was nonsignificant, $F1$ and $F2 < 1$.

(c) The effect of morphological bias was obtained with THOUGH contexts, $F1$ (1,44) = 4.85, $p < .05$, $F2$ (1,44) = 4.23, $p < .05$, but not with IF contexts, $F1$ (1,44) = 1.31, $p > .25$, $F2$ (1,44) = 1.13, $p > .25$, or with main clause contexts, $F1$ (1,44) = 1.07, $p > .25$, $F2$ (1,44) < 1 (see Table 6). There was no interaction between conjunction and nonmorphological bias, all Fs < 1.

(d) The morphological bias effect with THOUGH occurred mainly when the biasing context contained a form of BE (see Table 7), $F1$(1,44) = 4.99, $p < .05$, $F2$(1,44) = 4.33, $p < .05$. The morphological bias effect was not significant for THOUGH contexts without BE, for IF contexts with or without BE, or for main contexts with or without BE, all Fs < 1.

2. *Unambiguous Sequences in Final Clauses*

Analysis of variance of the log scores of response times for unambiguous trials using structural bias, morphological bias, conjunction, and target number as variables showed the following effects:

(a) There were no overall effects of contextual morphological bias or within-clause structural bias (see Table 8).

(b) There was an interaction between morphological bias and conjunction, $F1$ (2,46) = 3.82, $p < .05$, $F2$ (2,40) = 2.3, $p <$

TABLE 6
MEAN RESPONSE TIMES FOR AMBIGUOUS FRAGMENTS DEPENDING ON MORPHOLOGICAL BIAS AND CONJUNCTION

	Nonpredicted bias	Predicted bias	Bias effect
If	718	675	43
Main	670	655	15
Though	692	612	80

TABLE 7
MORPHOLOGICAL BIAS EFFECTS FOR AMBIGUOUS FRAGMENTS DEPENDING ON PRESENCE OR ABSENCE OF IS/ARE IN THE CONTEXT

	IS/ARE present	IS/ARE absent	Difference
If	35	53	−18
Main	5	28	−23
Though	120	36	84

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TABLE 8
MEAN RESPONSE TIMES FOR UNAMBIGUOUS FINAL CLAUSE FRAGMENTS DEPENDING ON MORPHOLOGICAL AND STRUCTURAL BIAS

	Singular target	Plural target	Bias effect
	Morphological bias		
Singular bias	709	737	28
Plural bias	737	721	16
	Structural bias		
Singular bias	702	742	40
Plural bias	744	717	27

.25 (see Figure 1a). This was due to a bias effect for IF contexts, $F1(1,46) = 12.58$, $p < .001$, $F2\ (1,40) = 13.2$, $p < .001$, but not for THOUGH contexts, both Fs < 1, or for main clause contexts, $F1\ (1,46) = 2.95$, $p > .05$, $F2\ (1,40) = 3.27$, $p > .05$. The bias effect in IF contexts was significant for singular morphological biases, $F1(1,46) = 13.6$, $p < .001$, $F2\ (1,40) = 15.1$, $p < .001$, but not for plural morphological biases, $F1 = 1.39$, $F2 = 1.54$.

(c) The bias effect of within-clause structure was confined to THOUGH contexts, $F1\ (1,46) = 7.7$, $p < .01$, $F2\ (1,44) = 7.7$, $p < .01$; it was marginally significant for main clause contexts, $F1$ and $F2 = 3.1$,

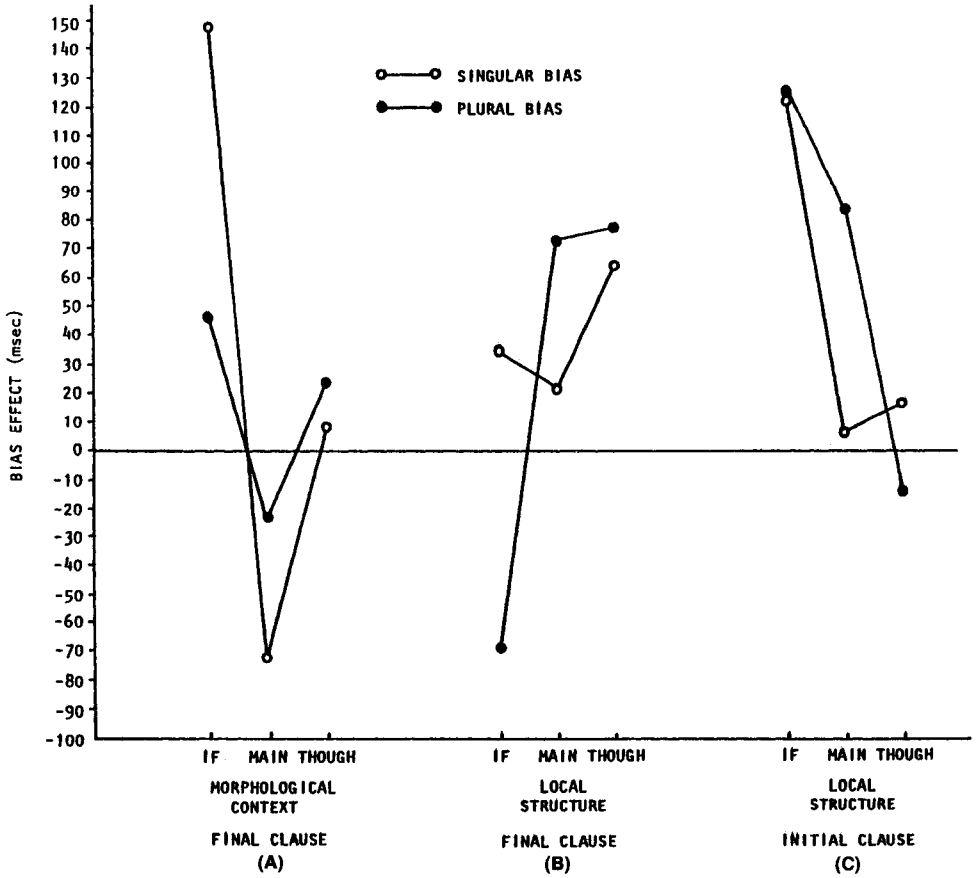

FIG. 1. Bias effects for unambiguous fragments.

$p < .10$, and nonsignificant for IF contexts, both Fs < 1 (see Figure 1b). There were no apparent differences between within-clause singular and plural biases.

3. Unambiguous Sequences in Initial Clauses

Analysis of variance of the log scores of response times from unambiguous initial clause trials using structural bias, conjunction, and target number as variables showed the following effects:

(a) The predicted structural bias effect occurred, $F1$ (1,23) = 12.9, $p < .01$, $F2$ (1,10) = 1.94, $p < .25$.

(b) There was an interaction between structural bias and conjunction, $F1$ (2,46) = 4.25, $p < .025$, $F2$ (2,20) = 5.74, $p < .025$, due to a strong effect of structural bias in IF clauses, a weak effect in main clauses, and no effect at all in THOUGH clauses (see Figure 1c). The bias effect was significant for IF clauses with singular bias, $F1$ (1,46 = 9.56, $p < .01$, $F2$ (1,20) = 51.6, $p < .01$, and with plural bias, $F1$ (1,46) = 9.23, $p < .01$, $F2$ (1,20) = 49.8, $p < .01$, for main clauses with plural bias, $F1$ (1,46) = 2.19, $p < .25$, $F2$ (1,20) = 11.8, $p < .01$, but not for main clauses with singular bias or for THOUGH clauses, all Fs < 1.

4. Comparison of Ambiguous and Unambiguous Final Clause Data

A combined analysis of variance of the log scores for ambiguous and unambiguous trials using trial type, morphological bias, conjunction, and target number as variables showed the following effect:

Response times were faster overall for ambiguous trials than for unambiguous trials (671 vs. 719 milliseconds), F (1,23) = 18.8, $p < .001$. This difference also occurred when we restricted the analysis to materials that were completely parallel between ambiguous and unambiguous materials, that is, for cases in which the contexts had a form of BE and the target was IS or ARE (688 vs. 727 milliseconds), F (1,1104) = 6.81, $p < .01$. This was nearly as large whether the target was consistent (722 milliseconds) or inconsistent (734 milliseconds) with the local structure of unambiguous phrases.

Discussion

The results replicate previous findings and demonstrate that the reading time paradigm is sensitive to organizational factors during sentence comprehension. We found that morphologically marked context exerted a large effect on ambiguous phrases, while nonmorphologically marked context had hardly any effect at all. The morphologically marked effects themselves were greater when the contextual verb was identical with the target verb. The primary results support the predictions made by the NU model of interaction between levels. Contextual information and local structure interact, and they interact in different ways depending on the nature of the contextual information, the nature of the local structure, and the semantic relationship between the context clause and the target clause.

In the introduction, we developed the proposal that comprehension involves the simultaneous development of representations at distinct levels of analysis. During comprehension these levels interact via a set of perceptual strategies, schemata that provide formulaic canonical relations between levels. These strategies allow the hypothesis of an analysis at one level as a function of another. At each level of representation there are natural, relatively independent units; for example, at the semantic level, the proposition; at the syntactic level, the word. By definition, complete representations of these units can interact most freely with each other and with other levels of processing. Accordingly, semantic–lexical interactions occur most strongly at those points in the processing of a sentence that correspond to the boundaries of such units. Previous context can exert specific effects—modifying hypotheses about the upcoming target word—most strongly at such points, for example,

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after propositional closure. The various effects that we found occurred because of differences in the availability of different levels of representation of the context depending on whether the context is IF, THOUGH, or an independent clause. The specific processes relevant to the current experiment are:

(a) Superficial, morphological information is more available following a THOUGH clause than it is following an IF or main clause. The evidence for this is: For IF and main clause contexts preceding an ambiguous phrase, the morphological and nonmorphological bias effects were both negligible; for THOUGH contexts the morphological bias effect was large, but the nonmorphological bias effect was negligible. These results suggest that the small morphological effects observed with IF and main clause contexts operate via more abstract representations, while those for THOUGH clause contexts are also sensitive to more superficial representations. Further support for this is the fact that the morphological effect of THOUGH was limited to cases with an explicit form of BE in the context clause.

(b) Ceteris paribus, the gerund interpretation of an ambiguous critical sequence should be more salient than the adjectival interpretation because of its greater salience as an independent proposition. Supporting this was the fact that the only effects of a context clause on reading time occurred when the listener was biased to expect a singular interpretation of a phrase: (1) The only independently significant effect of nonmorphological (i.e., semantic) context that occurred was for those cases in which the nonmorphological bias was toward the gerund interpretation of the ambiguous phrase. (2) The effects of morphological bias following an ambiguous phrase were much stronger when the contextually-determined interpretation was the gerund. (3) The bias effect of IF clauses on unambiguous phrases only occurred when the bias was towards the gerund interpretation. However, there was no asymmetry between singular versus plural interpretations based on the local structure of unambiguous phrases. These results suggest that integration of local information with contextual information occurs more easily at those points in processing that involve the hypothetical completion of a propositional unit.

The asymmetries between singular and plural contextual expectations can be attributed to the fact that the canonical word order (in this case, associated with the GER strategy) leads most directly to the completion of a propositional unit. Hence, when "landing planes" is heard, the gerund interpretation, corresponding to a verb–object reading, results automatically in perceptual closure vis-à-vis that interpretation, and integrates the phrase with available information from the context. If the context is consistent with the GER reading assigned to the ambiguous phrase, predictions (that are consistent with the reading and the context) about the upcoming word(s) are accepted. In particular, the gerund structure requires that it be the subject of a verb in the singular, usually a form of BE or a psych-verb (e.g., "seem," "upset," etc.). If the context is inconsistent with the gerund interpretation, that interpretation leads nowhere, leaving the field clear for the simultaneously developing adjectival interpretation. Since at that point, the adjectival interpretation is itself less complete as a propositional unit, the effects of an unexpected singular verb are less marked.

Our major findings are consistent with the predictions of the NU model. Certain aspects of the results allow us to speculate further about the details of how the model works. For example, we confirmed the fact that responses following unambiguous phrases are longer than those following ambiguous phrases.[3] Most striking is the fact

[3] Tyler and Marslen-Wilson also reported that verb reading times were faster following ambiguous than following unambiguous phrases. Prima facie, such a result is inconsistent with an undifferentiated context-driven model, since it indicates that both meanings of an ambiguous phrase are immediately

that this is true even when the target verb is consistent with the locally unambiguous phrase. This suggests that when a locally unambiguous phrase corresponds to a proposition, a further process occurs, one that assigns the meaning and removes the local morphological information from attention. The effects of this process, often referred to as "recoding," have been extensively studied at explicit clause boundaries. For example, detection of tones and performance on other tasks diminishes briefly at such points (Abrams & Bever, 1969; Bever & Hurtig, 1975; Seitz & Weber, 1974). Most germane to our present discussion is the fact that word-reading time increases at the end of a clause (Aaronson, 1976; Just & Carpenter, 1980). On our interpretation, this process interferes with the verb reading time.

The process of assigning a fixed meaning to a phrase is different from the process of constructing a hypothetical structure. In discussing the application of this distinction to the semantic analysis of whole clauses, Bever et al. stated: "During a clause listeners construct hypotheses about possible semantic/syntactic relations. At the end of a clause the listener chooses a particular analysis and discards others. . . ." (1973, p. 285). Apparently the process of "choosing" one meaning for a within-clause unambiguous phrase and "discarding" others can draw attention away from external tasks. In previous discussions, it has been shown that the process that occurs at this point "fixes" the interpretation in a relatively abstract form (Caplan, 1972; Townsend & Bever, 1978).

The fixing process interacts with the NU model in the following ways:

(1) Perceptual strategies pair morphological sequences with potential propositional organization.

(2) A morphological sequence with more than one such pair is integrated with any available morphological or semantic information, as a guide to fixing the most consistent interpretation. According to the NU constraint the extent of this integration for each potential structural analysis corresponds to the propositional completeness of that analysis.

(3) A morphological sequence with only one such locally consistent pair (i) is fixed semantically (ii) regardless of its propositional completeness.

As we noted above, principle (2) explains why the effects of context are greater for gerund than adjectival forms. It also predicts that morphological contextual information has an effect in THOUGH contexts. Principle (3) explains why (i) unambiguous reaction times are slower overall (because of the processing load involved in "fixing" the meaning); and (ii) why the effects of local structure are equal for unambiguous gerund and adjectival phrases. There remains one unexpected fact—that IF contexts with gerund bias lead to significantly faster reading times for the singular, IS, than the plural, ARE, even when the local structure is unambiguously adjectival. This demonstrates that the strategies apply to all structures of the appropriate morphological form; when the semantic structure is consistent with an available contextual meaning,[4] it is briefly integrated, even if the structure is locally impossible. That is, a locally inappropriate gerund (e.g., "barking

available. Tyler and Marslen-Wilson, however, argued that since the target verbs were different following unambiguous phrases, the difference might be an effect of materials. In our design, we were able to compare reading time for IS or ARE following ambiguous and unambiguous phrases preceded by the same sort of contexts—containing a form of BE.

[4] We are assuming that the "morphological" effects of the contexts with unambiguous materials are via their effect on the meaning of the context. Note that even in the ambiguous phrase materials, IF "morphological" gerund contexts with BE did have a sizable bias effect (75 milliseconds). Further evidence is that the bias effect of IF gerund context on unambiguous phrases is even larger with contexts and targets other than a form of BE. We found that in the ambiguous materials the effect of non-BE contexts was smaller in THOUGH contexts.

dogs'') is temporarily assigned a gerund structure as well as an adjectival one. If the preceding context supports the gerund interpretation, the listener briefly attempts an integration, presumably to reject it on fuller analysis. That is, the listener is caught in a brief garden path. If the verb reading task appears just at this point, reading times to the gerund interpretation will be facilitated. It is not predicted that an adjectival context would briefly override a gerund, because the adjectival structure does not integrate with the previous context as strongly.

This interpretation predicts that reading times for a singular verb following an unambiguous adjectival structure preceded by a gerund context are as fast as the corresponding singular reading times following an ambiguous phrase. In fact, this is what we found; the reading time for IS following an ambiguous phrase preceded by an IF gerund context (morphological bias, with forms of BE) was 628 milliseconds. The reading time for the corresponding unambiguous cases was 601 milliseconds.

These considerations are not conclusive since they involve hypotheses and constructs that the experiments were not designed to confirm or disconfirm. They do, however, give a fuller potential picture of how the IS/ARE reading task interacts with ongoing processing. When the verb coincides with a point of potential contextual integration, the reading time interacts with the processing of available context, even before the meaning of the local phrase has been fixed. In unambiguous cases, with no opportunity for contextual interaction, the reading time competes with the process of fixing the meaning, leading to longer overall times.

These results clarify the nature of the interaction between one level and another during sentence comprehension. They also provide the basis for a clearer definition of the ways in which ''context'' can be used. It is common sense that contextual information usually flows ''forward,'' clarifying expectations and setting acceptable criteria for what will be heard next. A technical definition of context in terms of the comprehension model we are presenting would require that ''context'' be defined as ''an analysis of the speech signal which contains a complete unit at any level of representation, and specifies a relation to unit(s) at another level.'' This leaves intact the fact that such analyses ordinarily will be completed in a forward manner.

A number of our results show how the forward flow of information depends on the major relations between clauses. For example, initial subordinate clauses can affect the reading time of verbs in a final main clause, while initial independent clauses do not (Bever, 1970). This suggests that an initial subordinate clause marker immediately sets the comprehension system to expect a following main clause with which it will be integrated. In the absence of such a marker, the system assumes that a single-clause sentence is being heard, and analyzes it in isolation. This is consistent with the earlier findings that initial subordinate clauses do not show evidence of being as strong independent units as do main clauses (Tanenhaus & Carroll, 1975).

As we reviewed above, the treatment of a subordinate clause and its anticipated relation to a following main clause depends further on what kind of clause it is. Consider what occurs when an initial adversative clause is followed by a main clause. We have demonstrated in a number of experiments, including the present one, (see also Townsend & Bever, 1978; Townsend, in press) that the information in an initial THOUGH clause is retained in relatively literal form. In terms of the present discussion, such a clause is relatively poor as an effective semantic context, since it does not state a univocal relation between the syntactic and semantic levels of representation. In fact, our current and previous results support the view that it is the following main clause which provides the context for the initial THOUGH clause. The interpretations of locally unambiguous

phrases in the later clause are unaffected by the content of an initial THOUGH clause, but greatly affected by the content of an initial IF clause. Conversely, locally unambiguous phrases in an initial THOUGH clause do not affect verb reading time, indicating that an initial THOUGH clause is not given a full semantic analysis while it is being heard; this result contrasts with those for initial IF and main clauses.

The technical definition of context above allows for such "backward" flow of information as we found for THOUGH contexts. Indeed, a moment's thought clarifies that such backward interactions must occur as well within words and phrases. It remains for future research to probe how such interactions occur within clauses.

Our theory and results render irrelevant the apparent controversy over the claim that syntactic analysis is "autonomous" during comprehension (Cairns, Note 1; Cowart, Note 2; Forster, 1974, 1979; Tyler & Marslen-Wilson, 1977). All parties to this controversy agree that sentence comprehension can include the development of acoustic, syntactic, and semantic representations. We have proposed a working hypothesis about the major constraint on the interactions between these representations: they occur most naturally with reference to complete units at each level. This intuitively obvious constraint has the automatic consequence that different aspects of representation can be shown to be relatively autonomous at points that do not correspond to natural units within levels. In the present article we have explored how interactions do occur at such points and how they are constrained by specific markers and hypotheses.

REFERENCES

AARONSON, D. Performance theories for sentence coding: Some qualitative observations. *Journal of Experimental Psychology: Human Perception and Performance*, 1976, **2**, 42–55.

ABRAMS, K., & BEVER, T. G. Syntactic structure modifies attention during speech perception and recognition. *Quarterly Journal of Experimental Psychology*, 1969, **21**, 280–290.

BEVER, T. G. The cognitive basis for linguistic structures. In J. R. Hayes (Ed.), *Cognition and the development of language*. New York: Wiley, 1970.

BEVER, T. G. Functional explanations require independently motivated functional theories. In R. E. Grossman, L. J. San, and T. J. Vance (Eds.), *Papers from the parasession on functionalism*. Chicago: Chicago Linguistic Society, 1975.

BEVER, T. G., GARRETT, M. F., & HURTIG, R. R. The interaction of perceptual processes and ambiguous sentences. *Memory and Cognition*, 1973, **1**, 277–286.

BEVER, T. G., & HURTIG, R. R. Detection of a nonlinguistic stimulus is poorest at the end of a clause. *Journal of Psycholinguistic Research*, 1975, **4**, 1–7.

BEVER, T. G., LACKNER, J. R., & KIRK, R. The underlying structures of sentences are the primary units of immediate speech processing. *Perception and Psychophysics*, 1969, **79**, 387–394.

BEVER, T. G., & TOWNSEND, D. J. Perceptual mechanisms and formal properties of main and subordinate clauses. In E. Walker and W. Cooper (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett*. Hillsdale, N.J.: Erlbaum 1979.

BOBROW, D., & FRASER, B. An augmented transition network analysis procedure. In N. Walker and L. Norton (Eds.), *Proceedings, International Joint Conference on Artificial Intelligence*. Washington, D.C., 1969.

CAPLAN, D. Clause boundaries and recognition latencies for words in sentences. *Perception and Psychophysics*, 1972, **12**, 73–76.

CAREY, P., MEHLER, J., and BEVER, T. G. Judging the veracity of ambiguous sentences. *Journal of Verbal Learning and Verbal Behavior*, 1970, **9**, 243–254.

CARROLL, J. M. Sentence perception and levels of syntactic structure. *Perception and Psychophysics*, 1978, **6**, 506–514.

CARROLL, J. M. & BEVER, T. G. Sentence comprehension: A case study in the relation of knowledge and perception. In *Handbook of Perception, Vol. 7, Language and Speech*. New York: Academic Press, 1976.

DAKIN, J. Explanations. *Journal of Linguistics*, 1970, **6**, 199–214.

FODOR, J. A., BEVER, T. G., & GARRETT, M. The psychology of language: An introduction to psycholinguistics and generative grammar. New York: McGraw–Hill, 1974.

FORSTER, K. I. The role of semantic hypotheses in sentence processing. In *Problemes actuels en psycholinguistique*. Colloques Internationaux du C.N.R.S. No. 206. Paris 1974.

FORSTER, K. I. Levels of processing and the structure of the language processor. In W. E. Cooper and E. C. T. Walker (Eds.), *Sentence processing:*

Psycholinguistic studies presented to Merrill Garrett. Hillsdale, N.J.: Erlbaum, 1979.

FORSTER, K. I., & OLBREI, I. Semantic heuristics and syntactic analysis. *Cognition,* 1973, **2,** 319–347.

FRAZIER, L., & FODOR, J. D. The sausage machine: A new two stage parsing model. *Cognition,* 1978, **6,** 291–325.

GARRETT, M. F. *Syntactic structures and judgments of auditory events*. Unpublished doctoral dissertation, University of Illinois, 1965.

HURTIG, R. The validity of clausal processing strategies at the discourse level. *Discourse Processes: A Multidisciplinary Journal,* 1978, **1,** 195–202.

JUST, M. A., & CARPENTER, P. A. A theory of reading: From eye fixations to comprehension. *Psychological Review,* 1980, **87,** 329–354.

KIMBALL, J. Seven principles of surface structure parsing in natural language. *Cognition,* 1973, **2,** 15–47.

KUNO, S., & OETTINGER, A. G. Multiple-path syntactic analyzer. In *Information Processing 1962*. Amsterdam: North-Holland, 1963.

SEITZ, M. R., & WEBER, B. A. Effects of response requirements on the location of clicks super-imposed on sentences. *Memory and Cognition,* 1974, **2,** 43–46.

TANENHAUS, M. K., & CARROLL, J. M. The clausal processing hierarchy . . . and nouniness. In R. E. Grossman, L. J. San, & T. J. Vance (Eds.), *Papers from the parasession on functionalism*. Chicago: Chicago Linguistic Society, 1975.

THORNE, J., BRATLEY, P., & DEWAR, H. The syntactic analysis of English by machine. In D. Michie (Ed.), *Machine Intelligence 3*. New York: American Elsevier, 1968.

TOWNSEND, D. J. Thematic processing in sentences and texts. *Cognition,* in press.

TOWNSEND, D. J., & BEVER, T. G. Interclause relations and clausal processing. *Journal of Verbal Learning and Verbal Behavior,* 1978, **17,** 509–521.

TYLER, L. K., & MARSLEN-WILSON, W. D. The online effects of semantic context on syntactic processing. *Journal of Verbal Learning and Verbal Behavior,* 1977, **16,** 683–692.

WANNER, E., & MARATSOS, M. An ATN approach to comprehension. In J. Bresnan and M. Halle (Eds.), *Linguistic theory and psychological reality*. Cambridge, Mass.: MIT Press, 1977.

WINOGRAD, T. Understanding natural language. *Cognitive Psychology,* 1972, **3,** 1–191.

WOODS, W. A. Transition network grammars for natural language analysis. *Communication of the ACM,* 1970, **13,** 591–606.

REFERENCE NOTES

1. CAIRNS, H. S. *Autonomous theories of the language processor: Evidence from the effects of context on sentence comprehension*. Unpublished manuscript, Queens College, 1980.
2. COWART, W. 1979. *A Defense of an Autonomy of Syntactic Processing Thesis*. Linguistic Society of America, 1979.

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