The underlying structures of sentences are the primary units of immediate speech processing[1]

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Two studies of the subjective location of clicks in spoken sentences indicate: (1) within-clause phrase structure boundaries do not significantly affect the segmentation of spoken sentences; (2) divisions between underlying structure sentences determine segmentation even in the absence of corresponding explicit clause divisions in the surface phrase structure. These results support a model of speech processing according to which listeners actively segment and organize spoken sequences into potential underlying syntactic structures.

According to Wilhelm Wundt, a sentence has two simultaneous psychological levels of organization. At the surface level the associative phrase relations are indicated by the order of the words in a sentence. At a deeper level the "logical" relational concepts, "subject," "predicate," and "object," express the internal relations among the words and phrases of a sentence. The actual order of the words in a sentence does not always correspond to or directly reveal the underlying relations. For example, in corresponding active and passive sentences the underlying relations are the same although the word orders differ:

> In the two sentences, *Caesar crossed the Rubicon,* and *the Rubicon was crossed by Caesar . . .* , the acting person ("subject") is in both cases, Caesar. But he is the topic of the statement only in the first and not in the second sentence [1900, p. 268].

The implications for behavior of this two-level syntactic analysis of sentences were not lost on Wundt. For him, the relations were not only logical but also psychological:

> The logical and psychological (domains) are not two things in opposition whose parts are separated, rather the logical relations among the words in the sentence are fundamentally *psycho*logical relations: logic has only abstracted them from the psychological process of thought in order to explore them according to their particular laws, carried back to a form as perfect as possible [1900, p. 262].

The logical relations in speech perception provide the basis for an active "apperceptive" synthesis of separate units in speech perception.

> . . . Relations of (this) type are . . . those which can occur between the mental concepts and their own component elements: the apperceptive relations. The intuition of activity . . . accompanies (these relations) not simply as one of the resultant effect of the relations, rather the activity precedes (the logical) relations; accordingly the relations themselves are conceived as coming into existence with the assistance of attentional processes. In this sense we view (the internal logical relations of stimuli) as *active* experiences [1877, pp. 291-292].

Wundt's analysis of underlying sentence relations and his claim that perceptual processes include the active synthesis of such apperceptive relations combine to present a particular view of sentence processing; listeners actively organize speech into segments defined in terms of underlying "logical" sentential relations. In this paper we present evidence that supports this view of the behavioral segmentation of speech.

Recently the distinction between the actual order of words in sentences and their underlying logical relations has been rediscovered and expanded in linguistic theory. Current transformational grammar also represents the insight that there are two levels of syntactic analysis for each sentence. The level of "surface phrase structure" describes the hierarchical phrase structure associations among adjacent words and clauses. The two example sentences mentioned by Wundt would be represented at this level as in Fig. 1. Each branching "node" of the phrase structure tree corresponds to a phrase structure "constituent." Each constituent corresponds to an association among the words and phrases that it contains. For example, in the first sentence the structure represents the fact that the words "the" and "Rubicon" are more closely related than the words "crossed" and "the."

The level of "underlying phrase structure" represents the "logical" relations which the words bear to each other. For instance, Wundt's two examples would be analyzed as having the same underlying phrase structure represented in the tree diagram in Fig. 2.[3]

In addition, current grammar specifies "transformational rules," which express the relation between the two levels of analysis.[4] Thus, every sentence has an underlying logical phrase structure, an apparent phrase structure, and a set of rules which derive the latter from the former. To "know" a language is to know a grammar which specifies all the possible underlying logical structures and the set of transformational rules which produces all the possible apparent phrase structures from them.

A great deal of attention has been given to the "psychological reality" of the structures and rules postulated in transformational grammars. The most notable success has been to show that the form in which sentences are understood

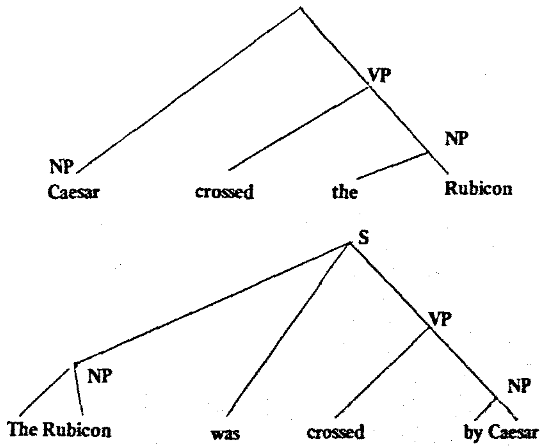


Fig. 1. Sample sentences with superficial phrase-structure trees.

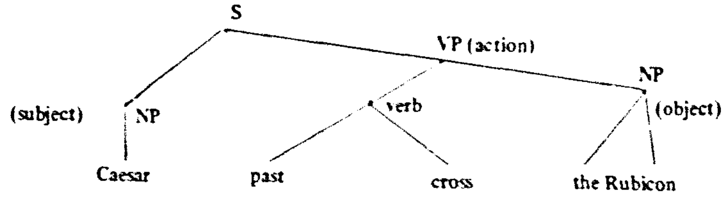
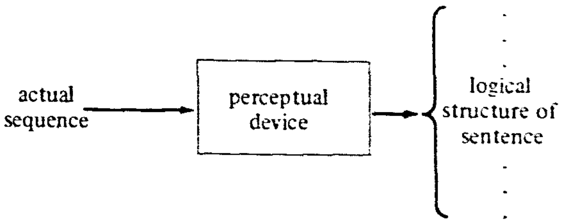


Fig. 2. Logical structure underlying the sentences in Fig. 1.

and memorized corresponds closely to the logical structure underlying them.[5] Thus, any model for speech perception proposed in this tradition includes a device which isolates the logical structure corresponding to each lexical sequence.



For such a perceptual device to operate efficiently, the actual sequence of words in a speech utterance must be segmented into those subsequences which correspond to a full sentence at the underlying structure level. For example, if one hears the sequence represented phonetically in Sentence 1, one must decide that it has two distinct sentence structures corresponding to it at the underlying structure level, and not more nor less.

(1) δaboylaiksgerlzgerlzluvboyz (i.e., the boy likes girls; girls love boys)

Failure to find the correct basic segmentation into sequences which do correspond to underlying structure sentences could impede comprehension. If a listener assumed that the second instance of "girls," above, was actually a spurious repetition, then he would be faced with finding an underlying structure for the following: *The boy likes girls love boys.* The problem is that this sequence has no single underlying syntactic structure.

There is no known automatic procedure which insures the proper segmentation of actual sequences. In cases like Sentence 1, however, segmentation strategies which separate underlying structure sentences in a discourse can utilize contextual, semantic, and pronunciation cues. The segmentation problem is much more complex for sentences embedded within other sentences. For example, consider Sentence 2a:

(2a) When he left everybody grew sad.

This has two deep structure sentences, each one corresponding to one of the "clauses" in the apparent sequence: "when he left, everybody grew sad." We shall represent this structural division into clauses at the surface structure level with parentheses, "()," and the corresponding underlying structure segmentation with brackets, "[]," e.g.,

(2b) ([When he left]) ([everybody grew sad])

If the wrong perceptual segmentation were attempted then correct perceptual analysis of the sentence would become impossible. For example, the listener might initially segment the first four words into a potential underlying structure sentence ("when he left everybody . . ."), but would then have two words left over ("grew sad") with no derivations from an underlying structure sentence.

A recent series of experiments has suggested that an initial strategy of speech perception segments together those lexical sequences which potentially correspond directly to underlying structure sentences (Fodor & Bever, 1963; Garrett, Bever, & Fodor, 1966; Bever, Fodor, & Garrett, 1966). Ss report the location of a single click in a sentence as having occurred closer to the point between two clauses than its objective location. For example, Fodor and Bever (1963) found that in Sentence 3 a click objectively located in "yesterday" or in "the" was most often reported as having occurred between those two words. Fodor and Bever argued that the systematic displacement of the click towards the point between clauses showed that the clause had relatively high psychological coherence, since it "resisted" interruption by the click.

(3) ([Because it rained yesterday]) ([the picnic will be cancelled])

Several experiments have shown that this systematic effect of the syntactic segmentation is not due to actual pauses or cues in the pronunciation of the sentence. Garrett, Bever, and Fodor (1966) used materials in which the exact identical acoustic sequence was assigned different clause structures depending on what preceded. Consider the sequence ". . . eagerness to win the horse is quite immature." If it is preceded by "your . . ." then the clause break immediately follows "horse." But if that sequence is preceded by "In its . . ." then the clause break immediately follows "win." The authors recorded the sequence with one initial sequence or the other and tested Ss ability to locate clicks in the different sentences. The results showed that the clause structure assigned each sequence affected the subjective location of the clicks. In a second study,[6] Abrams, Bever, and Garrett found similar results with sentences constructed by splicing words from a random list.

Scattered through the materials in these experiments were sentences which did not consist of two entirely separate clauses in the surface structure, but which had one clause embedded within another. For example, in Sentence 4a, there are two underlying structure sentences, but they are not literally reflected in the actual utterance as two distinct uninterrupted sequences.

(4a) ([The man ([who nobody likes]) is leaving soon])
(4b) ([Nobody likes the man ([who is leaving soon])])

Nevertheless, Fodor and Bever found that the extremes of the embedded clauses (e.g., Sentence 4a) are as effective in "attracting" the subjective location of clicks as they are in sentences with two distinct clauses (e.g., Sentence 4b). In some cases in the previous experiments, two underlying structure sentences corresponded to a sequence in which the division into two clauses was even less obvious in the actual structure. Consider Sentence 5a:

(5a) ([[The reporters assigned to George] drove to the airport])

(5b) ([The reporters ([who were assigned to George]) drove to the airport])

The sequence "... assigned to George ..." does not have the same intuitive distinctiveness as a clause in the surface structure of Sentence 5a as in Sentence 5b. Nevertheless, sentences in which the surface structure does not obviously reflect the underlying structure, like Sentence 5a, were found to affect the subjective location of clicks (e.g., clicks were displaced perceptually to the point following "George"). In certain cases one underlying structure sentence was so completely embedded within another that there was no trace of an explicit clause boundary in the apparent structure, as in Sentence 6 (taken from Garrett, Bever, and Fodor).

(6) ([[Only the metropolitan district of Hamburg] was leveled by the war])

In this sentence the point between "Hamburg" and "was" was found to be effective in attracting subjective click location even though this point is not a break between clauses in the surface phrase structure.

These data suggest that an early step in the organization of a string of words is to isolate those sequences in the surface order which correspond to underlying structure sentences. This strategy justifies the following experimental prediction for the subjective location of clicks:

H1: *Errors in location of clicks presented during sentences are towards those points which correspond to divisions between underlying structure sentences.*

This hypothesis received initial confirmation through the experiments described above. However, most of the results in the preceding experiments do not bear specifically on this hypothesis and are also subject to several orthogonal interpretations.

First, it might be the case that *any* phrase structure division marked in the surface phrase structure division of sentences has an effect on the click location. This was specifically claimed by Fodor and Bever (although they had examined primarily the effect of breaks between explicit surface structure clauses). Therefore, the previous experimental results also support the following hypothesis:

H2: *Errors in location of clicks presented during sentences are toward every surface phrase structure division, including those within clauses.*

The points in a sequence which correspond to divisions between the underlying sentences usually are also the largest phrase-structure divisions in the surface structure; it would be expected on H2 that these divisions would have maximum effect in attracting the subjective location of a click.

Second, most of the sentences in the previous experiments had an underlying structure division which was directly reflected in the surface phrase structure by an explicit clause division. That is, in general, the previous experiments would also support the following hypothesis:

H3: *Errors in location of clicks presented during sentences are only towards those points at which an underlying structure sentence division coincides with an explicit clause division in the surface structure.*

This paper presents two studies designed to explore these alternative hypotheses. First, we will examine the perceptual effect of within-clause surface phrase structure divisions, and show that these structural breaks do not reliably affect subjective click location. Second, we will present a study in which the sentences are carefully balanced for surface phrase structure, length, and other superficial features, but are systematically varied for the position in the actual sequence which corresponds to the division between two underlying structure sentences. In this experiment the division between the underlying sentences does attract clicks despite the lack of correlated divisions in the surface phrase structure. Thus, this paper supports Hypothesis H1, that a basic strategy of speech processing is actively to organize speech stimuli in terms of their underlying "logical" syntactic structure.

EXPERIMENT 1

English grammar defines a distinct surface phrase structure for each sentence. The surface phrase structure represents how the adjacent words are grouped together into "immediate constituents." We can define two types of immediate constituents, those which are clauses (i.e., directly derived from underlying structure sentences) and those which are "minor" phrases within clauses. For example, in Sentence 7 there are two main clauses, made up of the first 4 words and the last 10.

(7) ([When he stood up]) ([my son's book fell from the low and small table])

Within each clause, there are smaller phrase groupings; for example, in the sequence, "he stood up ...," the second two words are more closely grouped together than the first and the second words. This is called a "right-branching" structure since the phrase structure branches to the right. In contrast, "... my son's book ..." has a left-branching structure which groups the first two words more closely than the second two.

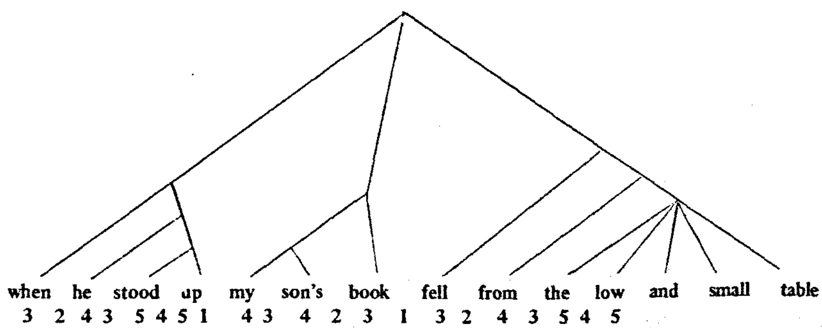


Fig. 3. Sample sentence with surface phrase structure tree and phrase structure depth indicators (Experiment 1).

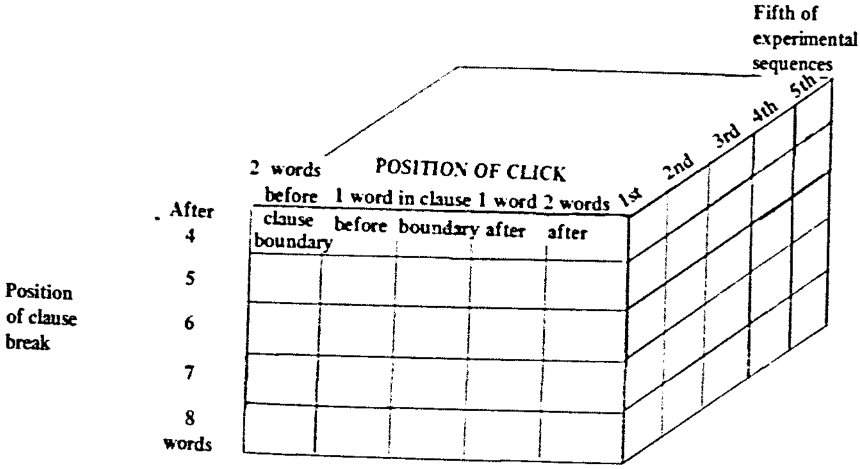


Fig. 4. Experimental design of stimulus materials in Experiment 1.

Finally, the sequence "low and small" has an intermediate ("ternary") structure since the first two words are as closely grouped together as the second two words. (See Fig. 3 for a surface phrase structure tree diagram of this sentence.)

Fodor and Bever claimed that the phrase is the perceptual unit of speech including "minor" phrases. However, in their study and in the other studies quoted above, the surface phrase-structure/clause-breaks studies usually corresponded to divisions between underlying sentences. The present experiment was undertaken to clarify whether or not "minor," within-clause phrase-structure breaks in the surface structure do affect click location. To investigate this we studied the perception of clicks in sentences in which the minor surface phrase structure within each clause differed systematically without associated differences in the underlying syntactic structure.

Stimulus Materials

Twenty-five English sentences, 12 words in length, were recorded with a normal subdued intonation. Each sentence was categorized as having a surface structure clause break after the 4th, 5th, 6th, 7th, or 8th word. The two words following the clause break of each sentence were monosyllables. The within-clause phrase structure was varied so that there were roughly the same number of left-branching, right-branching, and ternary-branching within-clause constituents immediately preceding and following the clause breaks (see Appendix 1).

The set of 25 stimulus sentences was recorded onto a master tape and five different orderings of this set were prepared from the master tape. Clicks were then placed on the other track simultaneous with each of the 125 resulting copies. For each sentence a click was placed in one of five positions relative to the clause break. The positions used were the major clause break itself, the middle of each of the two words immediately preceding the major break, and the middle of each of the two words immediately following the major break.[7] Each consecutive fifth of the five orders of stimulus sentences was balanced with respect to click placement relative to the clause break. In addition, each fifth of the five orders was balanced with respect to the positions of the clause break of the sentences. (See Fig. 4 for an outline of the design of the materials.)

The experimental procedure was the same as in Fodor and Bever. After each stimulus sentence, the S wrote down the sentence and indicated with a slash the position in the sentence at which he heard the click. Thirty Ss heard each experimental order. An equal number of Ss heard all the sentences in the right ear and the clicks in the left ear and vice versa. Ss were Harvard Summer School undergraduates who volunteered for paid participation in the experiment.

Results

The 150 Ss yielded 3704 click location responses of which 65.4% were errors; 46 responses were lost, usually due to a S's failure to indicate where he thought the click had occurred.

There were two main results: (1) Surface phrase-structure boundaries between clauses subjectively attracted interrupting clicks. (2) Surface phrase-structure boundaries within clauses had no consistent effect on the subjective location of clicks.

We first tested the prediction that clause boundaries would attract click location, to verify that our Ss and experimental techniques replicated the previous findings. For each click position relative to the break we compared the number of errors which went towards or into the clause break with the number of errors an equal distance away from the clause break. For example, a response to a click objectively in the word, "son's," in Sentence 7 that placed it in "my" was counted as confirming the clause-break hypothesis, while a location response in "book" was counted as disconfirming the response.[8] Of the error responses, 77% confirmed the hypothesis that the clause boundary attracts subjective location of clicks. This result was significant by sentence ($p < .001$).

Phrase-structure divisions within clauses were not effective in attracting click errors. We tested this by assigning each position within words and between words a number which corresponds to the number of constituents which that point in the sentence interrupts. For example, the different points in Sentence 7 would have been assigned phrase-structure depths indicated in Fig. 3 (only those points less than four syllables and spaces to either side of at least one actual click placement were included in this analysis. Appendix 1 presents the surface phrase-structure analyses we used).

Each location error was first measured for the number of syllables and spaces it spanned. (Spaces between words were counted as one-half syllable in duration.) For each error size we examined the prediction that more errors would be into the position which interrupts fewer immediate constituents (e.g., has a lower number in the above analysis). For example, this predicted that more location errors of one-half syllable to a click objectively in "stood" would precede "stood" than follow it; a location error of one syllable was predicted to go into the word, "he." Errors into the clause break, or an equal magnitude away from the clause break were not included in

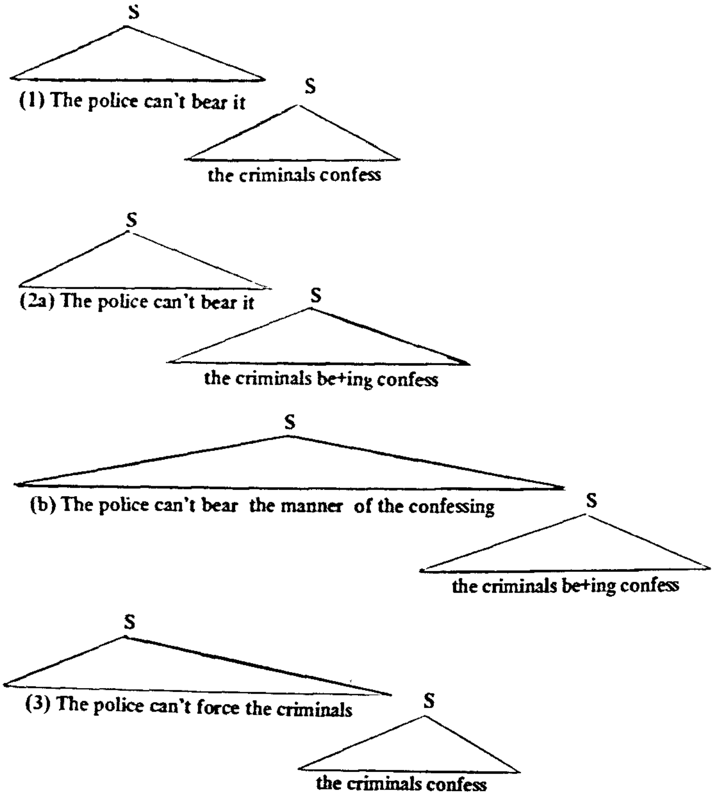


Fig. 5. Underlying syntactic structures for sentences with complement verbs (within-clause phrase structure is omitted). (Experiment 2)

this test, since we had already shown that the clause break does attract clicks.

There were 194 effective predictions governing the relative number of location errors of one-half to two syllables in size.[9] Of those, only 41.5% confirmed the within-clause phrase-structure hypothesis. In a reanalysis of our data M. Garrett [details reported in Garrett & Bever (in press)] found that the minor surface structure configuration weakly predicted the *direction* of small location errors ($p < .10$, two-tail) but not the specific location. Garrett also examined the correlation of the accuracy of clicks located at a break and the number of minor phrases which terminate or begin at that break. All correlations were low and nonsignificant (less than .2).

The failure of the surface phrase-structure predictions to be confirmed in general, leaves open the possibility that the underlying structure configuration of the sentences could account for the location errors, even in the absence of associated surface-structure clause breaks (H1). Although the stimuli in this experiment were not specifically designed to test H1, the underlying structure organization of a sentence coincided with surface order in some of the sentences. Consider Sentence 8 for example:

(8) ([The inexperienced pilot lost his breath]) (since [the plane dove [too fast]])

In the above sentence there are phrase-structure divisions which are not clause divisions but which nevertheless correspond to divisions between sentences in the underlying syntactic structure (marked with a square bracket). Of the 11 divisions of this sort which occurred in our materials, 8 attracted relatively more clicks (compared with the surface phrase-structure divisions an equal distance away for all error magnitudes), and 3 attracted relatively fewer clicks. To compare the attractive force of the underlying structure divisions, we categorized the within-clause structure analyses into those in which an underlying structure break coincided with the deeper break in the within-clause surface structure and those in which it did not. Of the 23 predictions in which the deeper surface structure break coincided with an underlying structure division, 20 confirmed the original within-clause surface-structure prediction. Of the 51 cases in which the predicted within-clause break did not coincide with an underlying structure division, only 19 confirmed the within-clause phrase-structure prediction. In nine instances the underlying structure-break prediction conflicted with the within-clause phrase-structure prediction; i.e., the shallower break in the surface structure corresponded to an underlying structure division between underlying sentences. In eight of these nine instances, the prediction based on the underlying structure was confirmed. Finally, in the four cases in which the within-clause phrase structure made no relative prediction, predictions based on the underlying structure were confirmed.

EXPERIMENT 2

The preceding results suggest that within-clause phrase structure has no consistent effect on click location. They also indicate that the most effective structural division governing errors in click location is the point corresponding to the division between sentences in the underlying structure. However, the stimuli in Experiment 1 were not critically designed to test this hypothesis, so the following experiment was also carried out.

Materials

Six sets of three sentences each were constructed in which the position of an underlying structure break was varied, while surface structure was held constant. The major variable in each set of sentences was the type of verb and complement clause. In one set of sentences the entire complement sentence is the direct object of the main verb ("nounphrase complement verbs"); in a corresponding set of sentences the subject of the complement clause is itself the direct object of the main verb ("verbphrase complement verbs").[10] Consider, for example, these three sentences (excluding surface structure clause divisions):

(9) Type 1–nounphrase complement
[$_1$ The corrupt police can't bear [$_2$ the criminals to confess] $_2$] $_1$
Type 2–nounphrase complement
(a) [$_1$ The corrupt police can't bear [$_2$ the criminal' confessing] $_2$] $_1$
(b) [$_1$ The corrupt police can't bear the criminals' confessing] $_1$
Type 3–verbphrase complement
[$_1$ The corrupt police can't force the criminals [$_2$ to confess] $_2$] $_1$

In the first type of sentence the entire embedded complement clause is the logical object of the main verb ("bear"); the underlying structure sentence corresponding to "the criminals confess" is directly reflected in the actual word order. In the second sentence type there are two possible underlying structures: (a) one identical to Type 1, and (b) one in which the object of the main verb ("bear") is the gerund itself (e.g., the object is "confessing" as in "They can't bear the criminal's confessing because of its maudlin style"); thus, in analysis Type 2b the actual sequence does not directly reflect an underlying structure sentence. In sentence Type 3 the subject of the embedded complement sentence is simultaneously the object of the main verb. Thus, in sentence Type 3 the surface order represents two distinct underlying structure sentences which overlap in the surface order. (The underlying structure configurations are outlined in Fig. 5.)

Our general hypothesis (H1) is that the basic unit of immediate speech processing is any sequence which corresponds to a "sentence" (single expansion of "S") at the level of underlying structure. This general hypothesis motivates two specific predictions for the subjective location of clicks in sentence Types 1, 2, and 3.

P1: Clicks in "verbphrase complement" sentences (i.e., with verbs like "force") will be located subjectively between the verb and following noun less often than in sentences with "nounphrase complement" (i.e., with verbs like "bear").

P2: Clicks in nounphrase complement verbs with gerund object (e.g., "the criminal confessing") will be located subjectively between the verb and noun less often than for the same verbs with sentence object (e.g., "the criminal to confess"). This prediction follows from the fact that Type 2 sentences have two potential underlying structure analyses; one similar to Type 1, and one not similar to Type 1.

To control for any possible differences in pronunciation of the three versions, six sentences were constructed by cross-splicing different parts of one sentence onto another. For example, the sequence "the corrupt police can't bear . . .," originally recorded as part of Type 1, was spliced onto ". . . the criminals' confessing," originally recorded as part of Type 2. Clicks were placed either in the main verb or in the middle of the following nounphrase. This yielded six experimental sentences from each set. A different experimental version of each of the sets of sentences was placed in different experimental groups (Appendix 2 lists these sentences.) In addition, 12 sentences without complements were included in the materials [they were part of a different experimental problem, cf. Bever, Lackner and Stolz (in press) for a discussion of these].

Experimental Procedure

The experimental procedure and instructions were exactly those used in Experiment 1. Ss were instructed to listen to each sentence, write it down following the auditory presentation, and indicate with a slash "/" where in the sentence the click had occurred. For each experimental order, half the Ss heard the speech in the right ear and the click in the left and half had the reverse earphone orientation. Ss were 160 M.I.T. undergraduates, native speakers of English, who volunteered for paid participation.

Results

Sixty-five per cent of the click location responses were incorrect. Both P1 and P2 were confirmed. To test the effect of the underlying structure segmentation we compared location errors into the position between the verb and nounphrase with errors of equal magnitude away from that position. For example, a response to a click objectively located in "bear," which subjectively places the click in the break between "bear" and "criminals," would count as attracted into the critical verb-nounphrase sequence, while a location placed immediately preceding the verb would count as repelled out of the sequence.

This analysis confirms the predictions based on the underlying structure (see the means in Table 1). The structure which attracted clicks most strongly into the middle of the complement verb/nounphrase sequence was the nounphrase complement sentences, Type 1. The least effective break was in the sentence with verbphrase complements, Type 3. The structure ambiguous as to whether or not there is an underlying structure division after the verb, Type 2, received an intermediate proportion of errors into the verb/nounphrase sequence. These results were consistent by sentence: sentence Type 1 received a larger proportion of errors into the verb/nounphrase sequence than the corresponding sentences for Types 2 and 3 for all six triplets of sentences ($p < .02$ by sign test, one-tail). These results are equally true of spliced and nonspliced versions of the sentences and were also significant by S. Two Ss (one heard speech in the left ear and click in the right ear, one in the reverse orientation) were selected randomly from each experimental group (16 groups). A significant majority of these had more errors intruding into the verb/nounphrase sequence for sentence Type 1 than for Type 3 ($p < .001$ by sign test, one-tail), more for Type 1 than for Type 2 ($p < .02$ by sign test, one-tail), and more for Type 2 than for Type 3 ($p < .02$ by sign test, one-tail).

The confirmation of P1 is largely due to differences in the location of clicks objectively in the verb. Table 1 presents the

Table 1
Proportion of Location Errors of Equal Magnitude into Position between Verb and Nounphrase in Experimental Sentences. Experiment 2

	Click objectively in the verb	Click objectively in the following noun	Mean
(1) Nounphrase verb and object complement sentence (Type 1)	.8	.8	.8
(2) Nounphrase verb and object complement gerund (Type 2)	.7	.7	.7
(3) Verbphrase verb and object complement sentence (Type 3)	.4	.7	.6

results for the sentence structures organized by objective click location. For all six sets of sentences, the subjective location of clicks objectively in the verb accounts for more of the difference between structures in Types 1 and 3 than does the subjective location of clicks objectively in the following nounphrase ($p < .02$ by sign test, two-tail). Similarly, the responses to clicks objectively in the verb accounts for more of the difference between Types 2 and 3 than do the responses to clicks objectively in the nounphrase for five out of six sets of sentences ($p < .04$ by sign test, two-tail). Finally, the clicks objectively in the verb and nounphrase contribute equally to the difference between Types 1 and 2. That is, when the verbs between two structure types differ (as between Types 1 and 3 or Types 2 and 3), the errors in the response to the clicks in the verb differ more than to the clicks in the following nounphrase. When the verbs are the same (as in Types 1 and 2) the in-verb and in-noun clicks contribute equally to the differences between the types. Thus, the main variable which determines the differences in subjective click location is the syntactic type of verb in which the click actually occurs.[11]

These results indicate that the syntactic division which affects subjective click location is the point in a sentence which corresponds to a division between "sentences" in the underlying syntactic structure. Current linguistic theory indicates that there is no basis for distinguishing the surface phrase structure of a verbphrase complement sentence like Type 3 from that of a nounphrase complement sentence like Type 1 (see Note 10). Thus, the marked differences in subjective click location must be due only to the underlying structure organization.[12]

As in previous experiments, there was a significant asymmetry in average click location correlated with earphone orientation. The average subjective location for the six critical sentences was −.08 syllable relative to the objective position of all clicks for Ss who heard the click in the left ear and the speech in the right ear. The average response for S with reverse earphone orientation was +.01 syllables. This difference was significant by sentence ($p < .02$ two-tail by sign test, two-tail for the unique sentences; in the experiment, a given S contributed data for only six sentences, but never more than one response to any given sentence, so a sign test was justified).

DISCUSSION

The two experiments in this paper were designed to refine the earlier findings concerning the effect of segmentation on the subjective location of clicks in speech. Previous results had indicated that explicit clause boundaries marked in surface phrase structure as well as underlying logical phrase structure, correspond to boundaries of processing units. However, there were three interpretations which were consistent with those results: (H1) any surface phrase-structure break which corresponds to a division between underlying structure sentences is an effective unit; (H2) all surface phrase-structure divisions correspond to units and the "larger" the division in the surface phrase structure (in terms of the number of nodes it separates) the larger the effectiveness of the sequence bounded by that break; and (H3) only underlying structure sentences which appear as separate clauses in the surface structure are effective units.

In Experiment 1, we systematically varied the surface depth of the phrase-structure breaks within clauses to make it possible for a small effect to appear. We found no reliable tendency for the proportion of errors into a within-clause break to correspond to the relative depth of that break. Furthermore, Garrett and Bever (in press) examined the results from Experiment 1 and found no correlation between the effectiveness of a clause break and the number of phrase-structure units which end at a particular clause. In a different experiment, Bever, Lackner, and Stolz (in press) found no differences in the effect on click location of three kinds of within-clause structures: adjective-noun ("red ball"), verb-object ("hit ball") and subject-verb ("ball hit").[13] Recently, Bever, Fodor, and Garrett [(1966) discussed in Garrett & Bever (in press)] investigated the relative effectiveness of pairs of surface structure transitions which were superficially quite similar, but which differed by having or not having an "S" node in the surface phrase-structure tree. Consider the two examples in Sentence 11:

(11a) They watched [the light turn green]
(11b) They watched the light green car

The relevant difference between the two structures just after the verb is the presence of an additional node in the surface structure of sentence 11a. Bever et al found that this difference of a single node had a profound effect on the pattern of errors in click placement (i.e., more clicks intruded into the main verb nounphrase sequence in Sentence 11a). Together with the negative results from Experiment 1 in this paper, these findings support the following initial conclusion: a relative increase in the number of surface structure nodes defines a unit of immediate processing *only* if the increase is related to an underlying sentence-node in the logical structure. Thus, Hypothesis 2 above is not correct.

All the further evidence supports Hypothesis 1 and simultaneously invalidates Hypothesis 3. Bever et al had previously found a tendency (nonsignificant) for sequences with nonapparent divisions between underlying structure sentences to be more effective in "attracting" clicks than structures which did not correspond to underlying structure divisions. As pointed out in the introduction, several sentences in the previously published click-location experiments did not have explicit clause breaks in the surface structure, but nevertheless attracted clicks to points corresponding to underlying structure divisions. This finding was also supported by the 11 instances in Experiment 1 in which divisions between underlying structure sentences are not reflected in clause divisions in the surface structure, but nevertheless attracted clicks. Finally, Experiment 2 in this paper indicates systematically the effectiveness of divisions between underlying structure sentences in the absence of explicit division into obvious clauses in the surface phrase structure.

These results demonstrate that immediate segmentation of sentences is responsive to underlying structure sentences. However, there are various difficulties with each of the experiments we have presented. It is not clear whether all underlying structure divisions have an effect on perceptual segmentation, or whether this effect is limited to those underlying structure sentences whose relations are reflected in terms of adjacencies or particular "canonical" orders in the surface structure. For instance, in the examples below, it is not clear that both the first and second sequences will be treated as processing units. Both derive from the same underlying structure "sentences" *(my steak BE rare, my steak BE tender)* but only the first reflects this in the surface structure by having the shared noun come first rather than last.

(12a) I like my steak rare and tender
(12b) I like my rare and tender steak

In addition, there are several methodological difficulties which might account for the failure of recent experiments to show an effect of within-clause phrase structure on click location. Perhaps the effects of within-clause structure are masked by the proximity of large between-clause breaks in our materials. Support for this hypothesis is suggested by the fact that errors of half syllable do show within-clause phrase structure effects for clicks located two words before or after the major clause break, while clicks which are objectively closer to the break and errors which are larger do not show any effect (see Note 9). Also, while minor breaks do not appear to "attract" click location errors, it might be that they could effect the actual number of errors—that is, a click located in a relatively deep phrase-structure break might be more accurately located than a click in a relatively shallow break.

It would be surprising if minor phrase structure had no effect on segmentation at all: even according to the view that underlying structure organization is psychologically primary, a listener must isolate the major segments in a sequence. (This is at least logically prior to determining their deep structure relations.) Therefore, we expect that a more sensitive measure of perceptual segmentation will reveal effects of the major segments organized in the deep structure, such as "subject nounphrase," "object nounphrase," and so on.

It is our general view that a primary part of immediate speech processing is the isolation of underlying structure sentence-units. This does not mean that no other features of actual sentences can induce segmentation. For example, Garrett (1965) found that an introduced pause attracts clicks; Bever, Fodor, and Garrett found that a clause boundary obvious in the surface structure is more effective in "attracting" clicks than an implicit boundary. It is clear as well that major acoustic features can guide perceptual segmentation in the absence of structural divisions, e.g., sequences surrounded by major pauses in the signal, or extremely long sequences without internal structure can be treated as perceptual units (e.g., long proper names). In addition, listeners can attend to the surface structure of sentences to isolate minor differences in stress as aids to disambiguating certain kinds of phrases. Thus, our view that the underlying structure analysis of speech is a primary basis for segmentation describes what we ordinarily do, but does not restrict what we *can* do.

CODA: THE INTEGRATION OF PERCEPTUAL SEGMENTATION WITH SPECIFIC LEXICAL KNOWLEDGE

In a recent series of papers, Fodor and Garrett (1967) and Fodor, Garrett, and Bever (1968) suggested that listeners actively use their knowledge of the underlying structure potentialities of particular lexical items in sentence comprehension. They supported this view by showing that sentences whose verbs have several underlying structure possibilities (e.g., Sentence 13a) are more complex than structurally identical sentences whose verbs have only one underlying structure possibility (e.g., Sentence 13b). This claims that it is not only the actual, realized structure of a sentence which determines its complexity, but also the structural potentialities of the individual lexical items.

(13a) John *believed* Bill
(13b) John *punched* Bill

The differences between the three types of sentences in Experiment 2 were primarily due to effects on the clicks objectively located in the main verbs. This indicates that specific lexical knowledge of the verb itself is used as a guide in the segmentation of underlying structure sentences as well as in the apprehension of their structure.

The immediate influence of the verb type on segmentation suggests that listeners are sensitive to the potential underlying structure organizations which can follow a particular verb and guide their perceptual segmentation in terms of the expectancy that an underlying structure sentence division is about to occur. Consider the underlying structural possibilities of the following sample verbs:

	Example completion	Syntactic type
nounphrase complement:	(a) the criminals	direct object
	(b) the criminals to confess / confessing / 's confessing	complement sentence objects
the corrupt police can't *bear* . . .	(c) the criminals' confessing	gerund object
	(d) to confess / confessing	complement or gerund in which the logical subject is the same as that of the main verb
verbphrase complement:		
the corrupt police can't *force* . . .	(14e) the criminal (to confess)	direct object followed optionally by a complement clause

Thus, a verbphrase complement verb (like "force") *must* be followed immediately by a direct object; this knowledge can be used to predict that a new underlying structure sentence cannot begin immediately following the verb, so segmentation is not established at that point. On the other hand, most of the potential constructions following a nounphrase complement verb (like "bear") begin a new underlying structure sentence. It is our hypothesis that listeners use this knowledge of the possible structures that follow nounphrase complement verbs to establish a segmentation at the point following the verb, *as they hear it*. In contrast, as listeners hear verbphrase complement verbs they know (intuitively) that a direct object must follow the verb, so they do not establish segmentation of an underlying structure sentence break immediately following the verb. Thus, in Experiment 2, the verb type was the primary determinant of the pattern of errors to clicks objectivity in the verb. This interpretation is also consistent with the finding in Experiment 2 that the pattern of errors to clicks objectively in the following nounphrase is uniform across all structure types. In all three constructions the nounphrase coincides with the subject of an underlying structure sentence, regardless of its relation to the preceding verb. Consequently, as listeners hear the nounphrase, they establish segmentation of a new underlying structure sentence. Therefore, all clicks objectively located in the nounphrase have an equal (higher than random) tendency to be subjectively located as immediately preceding the nounphrase.

A general picture of speech processing emerges from these studies. As we hear a sentence, we organize it in terms of underlying structure sentences, with subjects, verbs, objects, and modifiers. In this process we ignore structural features which are not immediately useful to the discovery of the sentence's potential underlying structure (e.g., we ignore many details of surface phrase structure.) Rather than recapitulating the *full* grammatical derivation brought out in the linguistic analysis of a particular sentence, the underlying structure segmentation of sentences and organization within sentences is projected immediately and directly from the structural potentialities of the words in a sequence. It is in this way that the "logical structure" which Wundt considered fundamental to the perception of sentences is actively reflected in the immediate processing of speech stimuli.

APPENDIX 1
THE SENTENCES USED IN EXPERIMENT 1, WITH SURFACE PHRASE STRUCTURES INDICATED BY PARENTHESES

(Hiding ((my friends) hat)) ((the small girl) (laughed (at (his strange predicament))))

(John (ran (quite fast))) but ((we) (caught him (in (the narrow alley))))

(When ((he) (stood up))) (((my son's) book) (fell (from (the low table))))

(After (a few tries)) ((the boy) (beat (his father) (at (Chinese checkers))))

(The boy and girl) ((won and lost) (at cards) (during (the afternoon)))

(They) (fought (tooth and nail))) (to get (past (the huge angry crowd)))

(By (making (his plan) known)) (Jim) (brought out) (the (objections (of everybody)))))

((In order (to see out)) ((the small child) ((pushed up) (the windows)))

(To determine ((the tree's age)) ((those boys) (asked (the old (forest ranger))))

((In addition) (to (his wives))) ((the prince) (brought ((the court's) only dwarf)))

((The inexperienced pilot) (lost (his breath))) (since ((the plane) (dove (too fast))))

If (you (did ((call up) Bill))) (I (thank you (for (your trouble))))

(The guard) (took ((your aunt's) (purse ((in which) (she (had (ten dollars)))))))

(They) (asked (the mean old man) (to be kind (to (his dog))))

(Since ((she) (was free (that day)))) ((her friends) (asked her (to come)))

(When ((the new minister) ((called up) Fred))) ((the plan) (was (discussed thoroughly)))

((Any student) (who (is (bright but young)))) (would not have (seen it))

(That ((the matter) was ((dealt with) fast))) (was (a shock) (to Harry))

(That ((a solution) (could not be found))) (seemed (quite clear) (to us))

(After ((the dry summer) (of (that year)))) ((most crops) (were (completely lost)))

((The boy) (who was (waiting (in (the hall))))) (is (a new student))

((The lawyer) (who (couldn't (decide (what (to do)))))) ((sat down) (in disgust))

((Not quite all) (of (the (brand new) chairs))) ((were shipped) (that day))

(Because (coffee (spilled on (her (sky blue) dress)))) (she (went home early))

(The entire (skiing party)) (feeling (nice and warm)) (laughed and sang loudly)

APPENDIX 2
SENTENCE TRIPLES WITH DIFFERENT SYNTACTIC STRUCTURES USED IN EXPERIMENT 2

(1a) The general preferred the troops to fight against the advancing enemy.
(1b) The general preferred the troops' fighting against the advancing enemy.
(1c) The general defied the troops to fight against the advancing enemy.

(2a) The little girl hated her mother to cook her some cauliflower.
(2b) The little girl hated her mother's cooking her some cauliflower.
(2c) The little girl told her mother to cook her some cauliflower.

(3a) The shopkeeper desired John to pile some boxes in the corner.
(3b) The shopkeeper desired John's piling some boxes in the corner.
(3c) The shopkeeper directed John to pile some boxes in the corner.

(4a) The teacher wanted the guilty boy to inform on his classmates.
(4b) The teacher wanted the guilty boy's informing on his classmates.
(4c) The teacher tempted the guilty boy to inform on his classmates.

(5a) The corrupt police can't bear criminals to confess very quickly.
(5b) The corrupt police can't bear criminals' confessing very quickly.
(5c) The corrupt police can't force criminals to confess very quickly.

(6a) The prophet will like the people to renounce their indifference.
(6b) The prophet will like the people's renouncing their indifference.
(6c) The prophet will cause the people to renounce their indifference.

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NOTES

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3. For clarity of exposition we have labelled explicitly the particular logical functions of the phrases "subject," "predicate," and "object." As Chomsky (1965) has pointed out, these labels are redundant with the actual configuration of the underlying phrase structure tree. Throughout this paper we shall refer to such internal abstract structures as "underlying structure sentences." Such terminology does not assert that the underlying structure is composed of *actual* pronounceable sentences; rather, the term "underlying structure sentences" in this paper refers to an abstract unordered hierarchical and functional set of relations among the actual phrases included within exactly one expansion of "S" in the underlying phrase structure.

4. For example, a "transformation" attaches the tense marker to the verb to yield in the surface phrase structure the simple declarative sentence: CAESAR CROSS + past the RUBICON. The passive construction is described by application of a general "passive" rule which reorders the subject and object to produce the sequence: The RUBICON – past – BE + past participle CROSS by CAESAR, which is transformed ultimately into The Rubicon Be + past cross + participle by Caesar. See Chomsky (1965) for a general discussion, and Bever et al (1963) for a discussion of the affix-movement and passive transformations in relation to psychological issues.

5. cf. Miller (1962), Mehler (1963), and Mehler and Bever (1967).

6. Abrams, K., Bever, T. G., & Garrett, M. Syntactic structure modifies attention during speech perception and recognition.

7. Placing the click in sentences was achieved by disengaging the transport mechanism of the tape deck and manually moving the tape across the play-back head until the desired position was located. Using the same procedure the accuracy of all the locations was then judged independently by the three authors.

8. Responses larger than the distance between the objective click position and the clause break did not figure in this analysis. Thus, for example, a response to a click objectively in "son's" in Sentence 7, which placed the click in the word "low" or the word "up," would not be counted. In all, 27.9% of the error responses were excluded from this analysis because they were too large in one direction or the other.

9. Ideally, 400 within-clause phrase structure predictions could be made for the four error magnitudes in 25 sentences and five click positions. (Four error magnitudes x 25 sentences x 5 click positions =

Table A

½	1	1½	2	error size in syllables
52%	41%	33%	36%	% confirming within-clause phrase structure prediction

500 predictions–100 cases which involve the major clause break, e.g., errors of one-half syllable to clicks objectively in the word immediately before or after the clause break.) However, in many cases the prediction could not be tested either because the two points in the sentence had an equal phrase structure depth, or there were no errors made into either position. There was an interaction with error magnitude; errors of one-half syllable confirmed the within-clause phrase structure hypothesis more than the larger errors (see Table A–Location error distribution according to magnitude).

For the errors of one-half syllable there was a strong interaction with the objective location of the click and the tendency to confirm the within-clause phrase hypothesis. One-half syllable errors in response to a click located objectively in the clause break confirmed the within-clause phrase-structure hypothesis 23%; one-half syllable errors in response to a click located objectively two words before or after the clause break confirmed the within-clause phrase-structure hypothesis 71%.

10. See Rosenbaum (1967) for a justification of these underlying structure analyses. The potential clause boundaries after the object nounphrase in the surface structure (deriving from the underlying structure sentences) are deleted in all three types of complement sentences. A crucial test is the fact that reflexivization cannot extend across a clause boundary, but it can extend to *all* of the complement sentences. That is, while Sentence a is ungrammatical, Sentences b, c, and d are all fully grammatical. Thus, the linguistic evidence indicates that neither Sentence b (Type 1) nor Sentence c (Type 2) nor Sentence d (Type 3) have clause boundary following the object nounphrase in the surface structure.

(a) *John cried when himself was seen
(b) John can't bear himself to be seen
(c) John can't bear himself being seen
(d) John can't force himself to be seen

11. Clicks objectively in the verb contribute as much to the difference between structure Types 1 and 2 as do the responses to clicks objectively in the following nounphrase. This is somewhat surprising, since through the verb, sentence structure Types 1 and 2 are identical. How can the fact that a gerund (as opposed to a complement sentence) will follow the verb have an effect on the perception of a click coincident with the verb? The answer lies in the possibility that the mechanism of locating clicks in speech following the sentence is not only immediately perceptual, but also takes into account some of the stimulus which follows the click. Thus, after hearing the entire sentence (or a large part of it), the presence of a complement or gerund construction can affect the placement of clicks objectively preceding it (cf. Abrams, Bever, & Garrett; Bever, Lackner, & Stolz, for brief discussions of the behavioral nature of the location of clicks in sentences). In this paper we assume that the interaction of click location and speech segmentation is "immediate," without attempting to decide how much of the effect is due to "perceptual" processes and how much to "short-term memory."

12. However, some linguistic analyses of the complement sentences might provide differences in surface phrase structures that could account for some of the results. If there were a distinction in the phrase structure which would differentiate the two types of sentences in the surface structure it would be the presence of an "S"-node in the surface phrase structure of Type 1 and the absence of an "S"-node in Type 3. But even if there were a difference in the surface phrase structure it would still be the case that the potential difference would only be the extent of one phrase structure node; we found in Experiment 1 that differences of several phrase-structure nodes have little effect on click placement, unless one of the nodes coincides with a division between underlying sentences. At the very least the difference between structures like Type 1 and those like Type 3 in their effect on click location is a systematic confirmation of the results found in Experiment 1; if there is a difference of one node in the surface phrase structure, it is effective only if it coincides with a deep structure division. Furthermore, it would be difficult to motivate the intermediate effect of sentences of Type 2 by appeal to surface structure differences.

13. In their experiment they controlled for possible differences in pronunciation by using sentences produced by cross-splicing, and they systematically varied the transitional probability (TP). Although TP did affect the relative placement of clicks, these differences in the within-clause phrase structure depths did not.

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