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THE USE OF SYNTAX IN UNDERSTANDING SENTENCES

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The present study explored the processes by which people understand sentences. Simple sentences with subjects, verbs and objects, but with specific semantic anomalies, were constructed from naturally occurring sentences. Sentences so derived were given to participants in Expts. I and III to judge for sensibleness and to participants in Expts. II and IV to alter so that they made more sense. The results showed the existence of two levels of processing: hierarchical and left-to-right. Participants judging sensibleness depended only on a sentence's deep structure, processing its functional relations according to hierarchical priorities—subject first, predicate second, and subject and predicate in combination last. This was true for both actives and passives. Participants altering sentences, however, depended on both deep and surface structure. They showed an additional left-to-right processing, preferring to change words near the end of both actives and passives. This effect was explained by thematic prominence. It was also found that participants treated actors as a restricted part of the universe of things which can be acted upon.

An English speaker appears to understand a sentence while he is hearing it. This observation, taken naively, suggests that people process a sentence for its semantic information in a strict left-to-right order. Recent linguistic work on generative grammars (Chomsky, 1957, 1965), however, implies quite a different process. People must process a sentence for its deep structure—its underlying functional relations—in order to understand it, and this processing is necessarily hierarchical in character. The present paper describes two experiments which uncover some of the psychological properties of this hierarchical processing, and another two experiments which show that this hierarchical processing is independent of a distinct, but real, left-to-right processing of semantic content.

In the spirit of generative grammars, speakers must, at some point, understand sentences in terms of elementary functional relations. These relations, extracted by speakers from the sentences they hear, are contained in the kernel strings (as yet unformed basic sentences) which underlie the sentences. Consider *The clown amused the children*. This sentence contains the functional relations of: subject of the sentence (*the clown*), predicate of the sentence (*amused the children*), main verb (*amuse*), object of the verb (*children*), and so on (Chomsky, 1965). For the present study we singled out kernel strings with transitive verbs, choosing sentences like *The clown amused the children* and *The umpire was hit by the bat*. The functional relations of interest in such sentences were named, for brevity, subject (*clown, bat*), verb (*amuse, hit*) and object (*children, umpire*).

The main question we asked was: How do people process sentences for understanding in terms of these relations? To answer it, we gave participants of Expt. I partly anomalous active sentences to judge for sensibleness. This confirmed that people do process sentences hierarchically. In Expt. II we asked other students to alter the sentences so that they made more sense. These students, while reflecting the hierarchical structure of Expt. I, also seemed to show a left-to-right process. In Expt. III, therefore, we required other students to judge the sensibleness of both actives and passives. Here it was found that the subject, verb and object were pro-

cessed hierarchically, whether the sentence was in the active or passive voice. Expt. IV confirmed that, indeed, people also processed sentences in a left-to-right manner, for the subjects, verbs and objects of actives and passives were altered in different ways.

A second question we asked was: How do people represent past experience? Such experience is expressed in every sentence someone speaks. For example, speakers will generally accept some nouns as subjects and reject others. This is a reflexion of how speakers have represented experience—some things can act, but others cannot. Corresponding to subjects, verbs and objects, then, there are the semantic relations of actors, actions and goals of actions. These refer simply to the classes of things people will accept as subjects, verbs and objects. The first two experiments, then, were also designed to discover some of the properties of actors, actions and goals.

In the present experiments we have used mostly semantically anomalous sentences, and yet we wish to generalize to the processing of normal sentences. This is appropriate for two reasons. First, as described below, the parts of the anomalous sentences do come from normal ones, and second, it is only by studying how normal processing is disrupted (here by semantic anomalies) that we are able to infer anything about normal processing. This is the rationale of countless other psychological techniques.

EXPERIMENT I

Method

There are three steps in Expt. I. The first step was to have students compose natural sentences; the second was to construct what we will call derived sentences by systematically altering the natural sentences; and the third was to have raters judge the derived sentences for their sensibleness.

Natural sentences were obtained by Clark (1965) from 15- to 17-yr.-old girls who composed simple active and passive declarative sentences. They had been given, among other frames, the sentence frames, *The — —ed the —* and *The — was —ed by the —*, to fill in with words of their own choice. They were told they could use either regular or irregular past-tense verbs. In this manner 120 subjects composed a total of 960 active and 480 passive natural sentences. It was possible to change all passives into actives and vice versa. Expt. I was concerned only with natural and derived active sentences.

A total of 4096 different derived sentences, all in the active voice, were constructed for raters to judge for sensibleness. They comprised the 16 conditions (called 'derived sentences') shown in Table 1. These conditions break down into five main groups. In the 'no agreement' conditions (derived sentences 1–4), the subject, verb and object of the derived sentences were each chosen from a different natural sentence. In the 'subject–verb agreement' conditions (derived sentences 5–8), the subject and verb came from one natural sentence, but the object from another. The derived sentences of the 'subject–object', 'verb–object', and 'complete agreement' conditions were constructed in similar fashion. The derived sentences within the five groups of conditions, however, were each constructed with different properties. Within the 'no agreement' conditions, for example, derived sentence 4 had as its subject, verb and object, respectively, what was originally an object, a verb and a subject of different natural sentences. In all, half the derived sentences had as subjects what were originally objects of natural sentences, and half had as objects what were originally subjects of natural sentences. These properties are also indicated in Table 1.

The 4096 derived sentences were constructed in an iterative scheme, by use of the derivation matrix shown in columns 3–5 of Table 1. First, 16 natural sentences were sampled at random and numbered 1–16. The subjects, verbs and objects of the natural sentences were then mapped on to the subjects, verbs and objects of 16 derived sentences according to the entries of the derivation matrix. As an example, the subject, verb and object of derived sentence 5 were taken,

respectively, from the subject and verb of natural sentence 3 and the object of natural sentence 4. This operation produced 16 derived sentences, one for each derived sentence condition. To produce further derived sentences, the 16 natural sentences were renumbered by adding one to each of their indexing numbers and by giving the last sentence an indexing number of one. The renumbered natural sentences were then mapped on to 16 more derived sentences by means of the same derivation matrix. This procedure, by 15 successive renumberings of the natural sentences, generated 16 different sets of 16 derived sentences. Each of these 256 sentences was derived differently from every other; the subject, verb and object of each natural sentence had been used in every derived sentence condition exactly once. In all, 16 different sets of 16 natural sentences were subjected to this iterative operation to produce the total of 4096 derived sentences (256 per condition).

Table 1. *Actual and corrected mean ratings of* 16 *kinds of derived sentences*

(Italicized relations in the same row were taken from the same natural sentence.)

Derived sentence	Kind of agreement	Subject	Verb	Object	Actual mean	Corrected mean
1	No agreement	$Subj_1$	$Verb_5$	Obj_3	4·12	4·06
2		$Subj_2$	$Verb_1$	$Subj_{10}$	4·04	3·95
3		Obj_{15}	$Verb_{13}$	Obj_2	2·89	2·84
4		Obj_{14}	$Verb_9$	$Subj_{11}$	3·33	3·35
5	Subject–verb agreement	*$Subj_3$*	*$Verb_3$*	Obj_4	4·52	4·50
6		*$Subj_4$*	*$Verb_4$*	$Subj_{12}$	4·70	4·66
7		*Obj_{11}*	*$Verb_{11}$*	Obj_1	3·03	3·02
8		*Obj_{12}*	*$Verb_{12}$*	$Subj_9$	3·25	3·24
9	Subject–object agreement	*$Subj_5$*	$Verb_2$	*Obj_5*	4·23	4·20
10		*Obj_{13}*	$Verb_{10}$	*$Subj_{13}$*	3·31	3·31
11	Verb–object agreement	$Subj_7$	*$Verb_6$*	*Obj_6*	5·65	5·60
12		$Subj_6$	*$Verb_{14}$*	*$Subj_{14}$*	4·27	4·29
13		Obj_{10}	*$Verb_7$*	*Obj_7*	3·67	3·61
14		Obj_9	*$Verb_{15}$*	*$Subj_{15}$*	3·08	3·08
15	Complete agreement	*$Subj_8$*	*$Verb_8$*	*Obj_8*	6·78	6·78
16		*Obj_{16}*	*$Verb_{16}$*	*$Subj_{16}$*	3·39	3·39

Table 2. *Examples of each of the* 16 *kinds of derived sentences*

1. The cowboy road the pipe.
2. The president lassoed the man.
3. The speech smoked the calf.
4. The pipe lassoed the president.
5. The cowboy lassoed the speech.
6. The president read the man.
7. The pipe smoked the calf.
8. The calf lassoed the president.
9. The president lassoed the speech.
10. The pipe read the man.
11. The president smoked the pipe.
12. The cowboy read the president.
13. The speech lassoed the calf.
14. The calf smoked the man.
15. The cowboy lassoed the calf.
16. The speech read the president.

What these derived sentences are like can be appreciated from the examples of each given in Table 2. These 16 derived sentences, however, were *not* constructed from 16 natural sentences, as the above procedure requires, but from only three—*The cowboy lassoed the calf*, *The president read the speech*, and *The man smoked the pipe*. This was done, since it is easier to see the relation of the derived sentences to the natural ones in such a simplified example. That is, Table 2 is meant only to give the flavour of the derived sentences, not to provide examples of actual experimental material.

Each derived sentence was printed on an IBM data card by an IBM model 557 interpreter. Sixteen raters were each given 256 derived sentences to rate for sensibleness. In a counterbalanced design, each rater received the 16 output sentences from one renumbering of each of the 16 sets of natural sentences. The 256 sentences were well shuffled for each rater.

The raters were students enrolled in introductory psychology at Carnegie–Mellon University

fulfilling a course requirement. They were asked to judge the sensibleness of the sentences on a 1–7 rating scale on which 1 meant 'very nonsensical' and 7 meant 'very sensible'. They wrote their ratings directly on each IBM data card, finishing the task in about ½ hr.

Results

The mean ratings for the 16 derived sentence conditions are shown in Table 1. An analysis of variance showed that the 16 means differed significantly, both with the 16 students as the sampling variable ($F = 62{\cdot}57$; 15, 225 d.f.; $P < 0{\cdot}001$), and with the 16 sets of natural sentences as the sampling variable ($F = 88{\cdot}63$; 15, 225 d.f.; $P < 0{\cdot}001$). (All t tests reported below use as their denominator the more conservative error term of the former F test.)

It seemed necessary to apply a correction to these 16 means. Since the natural sentences were drawn at random from our sample of composed sentences, it was possible to find two or more natural sentences in one set of 16 with, say, the identical subject. This meant that derived sentence 11, with verb–object agreement, was in some cases actually a sentence with complete agreement, and should be considered derived sentence 15. The means were corrected by calculating the probabilities for duplications of actors, verbs and objects (all less than 0·04) and subtracting the appropriate ratings from the actual mean ratings; for example, derived sentence 11, which had verb–object agreement, was corrected by taking out the cases, in the arithmetic, for which there was actually subject–verb–object agreement. The corrected ratings, also shown in Table 1, differ only slightly from the actual mean ratings; the ordering of the conditions remains unchanged.

The first comparisons are to be made between the appropriate means to show which subjects and objects raters found acceptable. Several conditions demonstrated that subject-nouns made at least as good objects as did object-nouns. Derived sentences 1–2, 3–4, 5–6 and 7–8 differed in only one way by pairs. Derived sentences 1, 3, 5 and 7 had object-nouns as objects, and the corresponding derived sentences 2, 4, 6 and 8 had subject-nouns as objects. Sentences with subject-nouns were rated 0·20 scale units better than those with object-nouns, a small but significant difference ($t = 2{\cdot}14$; 225 d.f.; $P < 0{\cdot}05$). But subject-nouns made considerably better subjects than did object-nouns. Derived sentences 1 and 3, 2 and 4, 11 and 13, and 12 and 14 differed only as to whether their subjects contained subject-nouns or object-nouns. Sentences with subject-nouns again made more sense, but by the much larger mean scale difference of 1·26 ($t = 13{\cdot}60$; 225 d.f.; $P < 0{\cdot}001$).

A second set of comparisons was made among the means of derived sentences to show the basis of hierarchical processing of sentences. Derived sentences 1, 5, 9, 11 and 15 were compared, since they vary simply in what kind of agreement they contain. The derived sentences, listed from most to least sensible, were those with complete, verb–object, subject–verb, subject–object and no agreement (all pair differences but the last two successive differences were significant with at least $P < 0{\cdot}05$). The two largest differences, however, were between derived sentences with complete and verb–object agreement and between those with verb–object and subject–verb agreement.

Discussion

We will consider two important results of the preceding experiment. (*a*) The raters, clearly, had different lists of candidates for actors and for goals of actions. (*b*) Raters processed sentences using a set of hierarchical priorities by considering the acceptability of subjects first, the acceptability of predicates as a whole second, and the acceptability of the subject and predicate in combination last.

Actors and goals of actions differed in significant respects. By our definition, actors are things which can take actions—no matter how abstract the action—and goals of actions are things which can be acted upon. The raters distinguished actors and goals, but not into mutually exclusive classes. Actors seem to be more narrowly defined than goals, since subjects could generally replace each other more sensibly than they could replace objects. But most important, actors and goals were asymmetrical: subjects could replace objects easily, but not the reverse. This finding implies that actors are a narrowly defined proper subset of the possible goals. Things that act are but a small portion of those things that are acted upon.

A distinction should be made between possible and preferred subjects and objects. A clever speaker could compose a sentence which has as its subject any English noun he cares to choose. *Man*, as well as *honour*, are possible as subjects. Normally, however, an English speaker will not choose any noun as subject but will restrict himself, more or less, to a limited subset of nouns. As Clark (1965) found, he prefers human or at least animate, nouns as subjects and inanimate or abstract nouns as objects. When he thinks of things that act, he usually thinks of humans and animals, but when he thinks of things that are acted upon, he thinks of inanimate objects and abstract concepts. The present results point out that animate things can also serve as objects in the sense that subject–verb combinations allow the possibility with equal ease. The reverse, however, is not true. Inanimate and abstract nouns may not function as subjects very easily. It is the *possible* actors—things that *can* act—which are but a small portion of the *possible* goals of actions—those things that *can* be acted upon.

Speakers process a sentence for sensibleness in some specifiable manner. According to the present results, they place importance on three interrelated semantic requirements: (*a*) the subject must come from the class of possible subjects; (*b*) the predicate must make sense internally; and (*c*) the subject and predicate must make sense together. Breaking any one of these three requirements in a sentence caused a large drop in its rating of sensibleness. Requirement (*a*) was met in sentences which had subject-nouns, but not object-nouns, in the subject position. Not meeting requirement (*a*) alone caused a drop of 1·26 scale units ($t = 13{\cdot}60$; 225 d.f.; $P < 0{\cdot}001$). Requirement (*b*) was met in sentences with verb–object agreement, but not in those without. (Verb–object agreement here assumes that the object position contains an object-noun.) Not meeting requirement (*b*) alone caused a drop of 1·16 scale units ($t = 6{\cdot}22$; 225 d.f.; $P < 0{\cdot}001$). Requirement (*c*) was met in sentences with complete agreement, but not in those with just verb–object agreement. In sentences not meeting requirement (*c*) alone, there was a drop of 1·18 scale units ($t = 6{\cdot}33$; 225 d.f.; $P < 0{\cdot}001$). These three requirements clearly accounted for the largest differences in ratings among the 16 derived sentence conditions.

There was also evidence that requirement (*a*) must be satisfied first, then (*b*), and then (*c*). Requirement (*a*) was more important than (*b*): derived sentence 13, which satisfied (*b*) but not (*a*), was rated less sensible than derived sentence 1, which satisfied (*a*) but not (*b*) ($t = 2{\cdot}42$; 225 d.f.; $P < 0{\cdot}02$). Furthermore, requirements (*a*) and (*b*) were interdependent. Requirement (*b*), that verb and object agree, became more important when requirement (*a*) was satisfied than when it was not—a difference of 0·77 scale units ($t = 2{\cdot}91$; 225 d.f.; $P < 0{\cdot}01$). These last two results both indicate that requirement (*a*) takes precedence over requirement (*b*). Requirement (*c*), that subject and predicate make sense together, must necessarily be last. Sentences with subject–verb and subject–object agreement were only slightly more sensible than sentences with no agreement. Only when the subject and predicate both satisfied requirements (*a*) and (*b*), respectively, was there any substantial increase in sensibleness with agreement between the subject and parts of the predicate. It should be emphasized that this hierarchical ordering describes a set of conditional judgements, e.g. the judgement of the sensibleness of the subject and predicate together is not possible until both the subject and predicate make sense by themselves. There is no evidence that the ordering describes the temporal sequence of these judgements.

The model just presented for the way speakers process simple sentences, for sensibleness at least, predicts that speakers will find fault with partly anomalous sentences in specific ways. The next experiment was designed to test these predictions.

EXPERIMENT II

Method

The 4096 derived sentences of Expt. I were given to 16 other students, also drawn from introductory psychology at Carnegie-Mellon University, in exactly the same form that they were given to the 16 students of Expt. I. Expt. II participants were asked to read each sentence, cross out one lexical word (the subject-noun, verb or object-noun)—any one they chose—and replace it with a new word so that the sentence would make better sense. They were asked to do this for every sentence, even for those which already made good sense.

Results and discussion

Table 3 lists the percentage of subjects, verbs, and objects crossed out and replaced in each of the 16 kinds of derived sentences. The percentages for each derived sentence condition (each row) are based on 256 different sentences, 16 given to each speaker.

The changes students made in the sentences indicate they processed sentences at two independent levels: left-to-right and hierarchically. Again, the results show the difference English speakers perceive between actors and goals of actions.

What appears to be left-to-right processing is most obvious in the sensible sentences, but is evident in other sentences as well. Derived sentence 15 was an unchanged natural sentence and was rated in Expt. I as very sensible. In it students much preferred to change the object, crossing out the subject and verb much less and about equally often. Their preferences were similar for derived sentence 1, the sentences with no internal agreement. The assumption of this argument is that the right-most item—here, the object—is altered most often because it comes nearer the end of the sentence, and not because it is the object. This assumption is tested in Expt. IV.

There was also evidence for hierarchical priorities in processing, like those in

Expt. I, of the subject first, the predicate second, and the two together last. When subjects were of the wrong kind, i.e. object-nouns instead of subject-nouns, speakers changed them with a mean increased frequency of 21 percentage points. Students next demanded a whole predicate that made sense. In derived sentences 5 and 6, with

Table 3. *Percentages of subjects, verbs and objects changed for derived sentences to make sense*

(Derived sentence labels correspond to those in Table 1; percentages by rows add up to 100 except for rounding errors.)

Derived sentence	Kind of agreement	Subject	Verb	Object
1	None	19	25	56
2		17	30	54
3		39	23	38
4		41	31	29
5	Subject–verb	8	15	78
6		8	15	78
7		42	18	40
8		39	21	41
9	Subject–object	12	43	45
10		38	34	28
11	Verb–object	47	13	40
12		25	21	53
13		71	12	17
14		42	32	27
15	Complete	24	20	55
16		39	32	29

subject–verb agreement, students ignored subject and verb and changed the objects 78 per cent of the time. But when they did not change the object, they changed the verb more often than the subject, presumably to form agreement with the object, resulting in a better predicate. In derived sentence 9, which had subject–object agreement, again students largely ignored the subject and concentrated on changing the verb or object to form a sensible predicate. When predicates were well-formed, they were left relatively undisturbed. In derived sentence 11, with verb–object agreement, many students changed the subject, even though it was of the right class of nouns. When there was verb–object agreement but the subject was of the wrong class, as in derived sentence 13, students strongly objected to the subjects, changing them 71 per cent of the time. The last step in hierarchical processing is to demand that the subject and predicate make sense together. This step follows from evidence which implies that speakers first demand proper subjects and proper predicates independently.

The asymmetry of subjects and objects was also evident in Expt. II. Object-nouns were changed more often than subject-nouns when used as subjects (a mean difference of 21 percentage points) and when used as objects (3 percentage points). This result closely parallels the difference in Expt. I ratings which indicated that raters preferred subject-nouns in both subject and object positions.

Expt. II found speakers apparently processing sentences left-to-right at one level but hierarchically at another. This hierarchical ordering, however, is partly correlated with a left-to-right direction of processing. To show the independence of these two

levels, we designed Expts. III and IV, noting that in actives and passives the ordering of subject, verb, and object is reversed. Expt. III was meant to test whether active and passive forms of the same kernel string are processed equivalently and hence whether the hierarchical model holds under various transformations which preserve sense but not order.

EXPERIMENT III

Method

As in Expt. I, natural sentences were used to construct derived sentences which were given to raters to judge for sensibleness. In all there were 4000 derived sentences, comprising 20 derived sentence conditions. These 20 conditions, in turn, could be classified into four groups of conditions in a 2×2 design: five conditions were made up of active sentences derived from natural actives; five, of active sentences derived from natural passives; five, of passive sentences derived from natural actives; and five, of passive sentences derived from natural passives. The five conditions within each of the four groups consisted of the five agreement possibilities: no, subject–verb, subject–object, verb–object and complete agreement (corresponding exactly to derived sentences 1, 5, 9, 11 and 15 of Expt. I). The terms subject, verb and object, of course, refer to the underlying kernel strings for both actives and passives, so that in passives their left-to-right order is object, verb and subject. In this experiment there were no conditions in which subject-nouns were placed in the object position or object-nouns in the subject position.

An iterative scheme identical to that in Expt. I was also used here to generate derived sentences. Twenty sets of 10 active and 10 passive natural sentences—from the same source as in Expt. I—were put through the appropriate 20×3 derivation matrix to produce the 4000 derived sentences. An important property of this total number was that for every active there was a corresponding passive with the identical subject, verb and object. The sentences were given to 20 male undergraduates fulfilling a requirement for introductory psychology at The Johns Hopkins University, 200 to each, in a counterbalanced design as in Expt. I. The printing of the cards, shuffling of the decks, instructions and rating scales were the same as those used in Expt. I.

Table 4. *Mean ratings of active and passive derived sentences constructed from active and passive natural sentences*

Form of natural sentence ...	Active		Passive	
Form of derived sentence ...	Active	Passive	Active	Passive
Kind of agreement				
None	3·22	3·14	2·74	2·82
Subject–verb	3·72	3·53	3·26	3·44
Subject–object	3·42	3·40	3·30	3·26
Verb–object	4·91	4·80	4·33	4·32
Complete	6·57	6·35	6·50	6·39

Results

The mean ratings (shown in Table 4) were affected by only two factors: (*a*) the voice—active or passive—of the natural sentences, and (*b*) the kind of agreement within the sentences. Sentences derived from active natural sentences were rated significantly more sensible than those derived from passive natural sentences ($F = 18{\cdot}70$; 1, 3980 d.f.; $P < 0{\cdot}001$). Active and passive sentences derived from the same kernel string, however, were not rated differently. Kind of agreement affected the mean ratings significantly ($F = 409{\cdot}0$; 4, 3980 d.f.; $P < 0{\cdot}001$), but did not interact with the form of the natural or derived sentences. The order of the mean ratings for the five kinds of agreement replicates the findings of Expt. I.

Discussion

According to the last results, sentences were analysed for sensibleness in the same manner, regardless of whether they were active or passive. These results give no evidence which questions the hierarchical process model presented above, for the five kinds of agreement, had the same effects on ratings of active and passive sentences.

On the other hand, the students composed active and passive sentences that had different properties. As can be seen in Table 4, sentences with verb–object agreement were much more sensible when the natural sentence was active than when it was passive; the same holds true of other sentences, particularly those with no agreement. One interpretation of this is that people compose passives so that the object (the initial noun phrase) and verb do not form a very tight unit. This mimics what they do in composing actives from left to right: the subject and verb do not form a tight unit. Thus the 'information'-bearing part of the sentence is the surface predicate, i.e. the phrase following the surface subject (the initial noun phrase), and this is true for both actives and passives (see Clark, 1965). More generally, the lower sensibleness of the passive is related to Clark's (1965) finding that the passives people compose contain a greater variety of words than the actives they compose; the situations described in passives have less in common with each other than the situations described in actives.

It was conjectured that participants in Expt. II altered the objects so often merely because they were the last word processed. One question still remained unanswered: Would students also process passives in a left-to-right direction? Expt. IV, then, presented both actives and passives to other students to alter in the same manner as in Expt. II.

Experiment IV

Method

The 4000 derived sentences of Expt. III were given to a new group of 20 students, exactly as they had been given to participants in Expt. III and with the instructions given to participants in Expt. II. That is, students were to cross out any one of the lexical items (any word except *the* and *by*) in each sentence, regardless of its sensibleness, and replace the word with one that increased the sensibleness of the sentence. The students were Carnegie–Mellon undergraduates, as in Expts. I and II.

Results

The percentages of words altered in each of the 20 conditions are shown in Table 5. Each row is based on 200 sentences, 10 altered by each student.

Participants in Expt. IV, as is clear from Table 5, processed both actives and passives in a left-to-right direction. There were very small differences between sentences derived from natural actives and natural passives, but large differences between derived actives and passives. This is just the opposite of the results in Expt. III. Subjects were altered less in actives than in passives, and objects more. This was consistent for all 10 comparisons (significant at $P < 0{\cdot}001$ by a sign test). The active–passive comparison is clearest in the complete agreement conditions: the subject, verb and object percentages for actives closely match the object, verb and subject percentages for passives.

Table 5. *Percentages of subjects, verbs and objects changed for active and passive derived sentences to make sense*

Form of derived sentence	Kind of agreement	Form of natural sentence: Active Subject	Active Verb	Active Object	Passive Subject	Passive Verb	Passive Object
Active	None	14	46	40	18	40	42
	Subject–verb	8	26	65	7	21	72
	Subject–object	8	64	28	12	66	22
	Verb–object	44	24	32	53	21	26
	Complete	18	36	45	26	29	45
Passive	None	20	53	27	26	44	30
	Subject–verb	11	34	55	18	29	53
	Subject–object	12	72	16	21	65	14
	Verb–object	62	23	15	72	22	6
	Complete	45	33	22	40	39	21

GENERAL DISCUSSION

From these experiments emerges the view that people process the meaning of sentences in two separable ways: hierarchically and left-to-right. To review the evidence: Expts. I and III indicated that in rating sensibleness people judged the acceptability of the subject first in priority, the predicate as a whole second, and the subject–predicate combination last; participants in Expt. II altered sentences in a manner consistent with this process. This was a hierarchical process. In Expts. II and IV, on the other hand, there was an additional bias towards altering words further along in sentences, whether active or passive. This indicated a left-to-right process.

The phenomena described as left-to-right and hierarchical processing are closely related to structural descriptions linguists have made of surface and deep structure (Chomsky, 1965). Surface structure, in effect, indicates the structure of the linear succession of what is spoken, while deep structure indicates the functional relations among the spoken linguistic units. The same functional relations from deep structure can occur in sentences with widely varying left-to-right properties or surface structure. Surface structure must therefore be evaluated, at least in part, before deep structure is known. It is not too surprising that we found both components in the present experiments. It is important to make known, however, where and how surface and deep structure must be taken into account in psychological processes.

Judgements of sensibleness, in the present results, were not affected by surface structure. Sensibleness is a property of deep structure, as it should be. The model we presented for the process of judging is parallel to the set of rules in the base component of generative grammars (Chomsky, 1965). In the present description, the smallest constituents are judged for acceptability before the larger ones are. The judgement, in other words, starts at the bottom of the phrase-marker—a tree with labelled nodes—and moves up to successively higher nodes.

How a sentence is to be altered to become more sensible, however, depends on both surface and deep structure. Altering *The women crumpled the ball* is different from altering *The ball was crumpled by the women*, although judgements of sensibleness (and deep structure) are the same for both. This seems to imply that the alteration

of sentences is related to the left-to-right production of sentences. Because the realization of the object is first, instead of last, in passives, it is much less alterable after the sentence has been read. It is possible that this is merely a short-term memory phenomenon, and the last item in an auditory memory (see Neisser, 1967) is more readily retrieved and replaced.

Left-to-right processes, however, have been found in numerous other psycholinguistic experiments (Anderson, 1963; Clark, 1965; Duncker, 1945, p. 24; Johnson, 1967; Johnson-Laird, 1968*a*, *b*; Prentice, 1966; Turner & Rommetveit, 1968). The principal result has been that a linguistic unit takes on thematic prominence when it is first in a sentence. In simple sentences, the surface subject (the active's subject and the passive's object) states the theme of the sentence—what the sentence is about—and the remainder of the sentence states what is to be said about the theme (Halliday, 1967*a*, *b*). Thematic prominence can also be used to explain the left-to-right processing in the present study. The students altering sentences were loath to change the theme of the sentence, for psychologically the theme was a fixed topic and not easily altered, but the students were quite willing to change what was said about the theme. At the same time, thematic prominence has little to do with sensibleness, for subjects, verbs and objects make sense together, regardless of whether the subject or object is the theme. An explanation in terms of theme has intuitive appeal for anyone who has tried to alter nonsensical sentences. There is a strong tendency to feel that the theme is fixed (as in the 'mind's eye') and that it is the rest of the sentence that is nonsensical.

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