Q. Jl exp. Psychol. (1969) 21, 1–13

ON UNDERSTANDING LOGICALLY COMPLEX SENTENCES

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An experimental investigation was made into the meaning of eight types of *doubly-quantified* sentence, e.g. "*Every* medicine cures *some* disease," "*Some* disease is cured by *every* medicine." All the sentences were ambiguous, depending upon the interpretation of the quantifiers. Subjects classified diagrams representing different specific situations as truthfully or falsely described by the sentences. The classifications revealed that the order of occurrence of the two quantifiers had a crucial effect, causing active and correlative passive to receive different interpretations. This suggested that in the process of understanding an ambiguous sentence a bias towards one intepretation may be created by word order.

Introduction

There is a controversy about whether the active and passive voice are *always* synonymous (cf. Chomsky, 1957, 1965; Katz and Postal, 1964; Ziff, 1966; Katz and Martin, 1967). It seems to have arisen, in part, because of a failure to distinguish probable interpretations from possible interpretations. Consider, for example, this pair of *quantified* sentences:

(1) *All* philosophers have read *some* books.

(2) *Some* books have been read by *all* philosophers.

Both sentences, isolated from any context, are ambiguous in the same way. They mean either (a) all philosophers have read some books *or other*, or (b) all philosophers have read some books *in particular*. But, although both sentences have the same possible interpretations, it seems intuitively that these interpretations are not equally probable—they are not equally privileged. Sentence (1) seems more likely to receive interpretation (a), and sentence (2) seems more likely to receive interpretation (b). One aim of the present experiment was to test whether there was this difference in the privileged interpretations of a variety of logically complex sentences.

Is there any explanation why these sentences should have different privileged interpretations? A preliminary answer is provided by considering their symbolic form within the quantificational calculus (cf. Ch. 4 of Suppes, 1957). The existential quantifier (Ex) stands for "there exists at least one x . . .," and the universal quantifier (x) stands for "for any x. . . ." Let x range over philosophers,

y range over books, and R stand for the relation of "reading," then it is possible to express the two interpretations of the sentences in the following form:

(a) $(x)(Ey)(xRy)$ Every philosopher has read some books *or other*.

(b) $(Ey)(x)(xRy)$ There are some books *in particular* that every philosopher has read.

These symbolic interpretations have their quantifiers in the same order as the actual sentences for which they are assumed to be privileged. Hence, an explanation for the effect is that word order determines which interpretation is privileged. What comes first in a sentence receives more emphasis than what comes later (cf. Johnson-Laird, 1968*a*, *b*) and the first quantifier will, in the technical sense, *bind* the second quantifier. This is not a complete explanation, however, until an analogue for the technical notion of binding is found in everyday language. Such an analogue is revealed by an examination of the expressions which realize the existential quantifier, e.g. "some," "at least one," "several," "a few," etc. All of these expressions are essentially ambiguous. Compare the probable interpretations of "John has several girl friends" and "John always has several girl friends"; in the first sentence the reference is to some girls in particular, but in the second sentence it is to some girls or other. Where there is only a single quantifier in the sentence the ambiguity is trivial, but where there are two or more quantifiers it may be crucial. When "some" occurs first it will receive a greater emphasis according to the hypothesis about word order. This emphasis is more in accord with "some in particular" than "some or other," since emphasis is given to particulars rather than to vague generalities. The converse argument applies where the existential quantifier comes after the universal quantifier. This explains the privileged interpretations of sentences (1) and (2). But the explanation also applies to other sentences where intuition is a less certain guide, and by examining these sentences experimentally the theory is put to a more stringent test.

TABLE I

Twelve basic quantified "two-place" relations

1.	$(x)\ (Ey)\ (xKy)$	Every man knows some woman (or other).
2.	$(Ey)\ (x)\ (xKy)$	Some woman (in particular) is known by every man.
3.	$(y)\ (Ex)\ (xKy)$	Every woman is known by some man (or other).
4.	$(Ex)\ (y)\ (xKy)$	Some man (in particular) knows every woman.
5.	$(x)\ (Ey)-(xKy)$	Any man does not know some woman (or other).
6.	$(Ey)\ (x)-(xKy)$	Some woman (in particular) is not known by any man.
7.	$(y)\ (Ex)-(xKy)$	Any woman is not known by some man (or other).
8.	$(Ex)\ (y)-(xKy)$	Some man (in particular) does not know any woman.
9.	$(x)\ (y)\ (xKy)$	Every man knows every woman.
10.	$(x)-(Ey)\ (xKy)$	No woman is known by any man whatsoever.
11.	$(Ex)\ (Ey)\ (xKy)$	Some man knows some woman.
12.	$(Ey)-(x)\ (xKy)$	Some woman (in particular) is not known by every man.

(Ej) denotes the existential quantifier, (j) denotes the universal quantifier, and "—" denotes negation. It is assumed that x ranges over men, y ranges over women, and K denotes the relation of "knowing".

There are 12 basic quantified "two-place" relations, and these are listed in Table I in a symbolicm for and in a more or less idiomatic translation ("—" is the sign for negation). There are other logically equivalent formulations of these relations, any one of which may be expressed in English in a variety of ways. But the material selected for investigation was of the same form as sentences (1) to (8). This material was chosen in order to investigate three variables: *polarity*—whether the sentence is affirmative or negative, *voice*—whether the sentence is active or passive, and *word order*—whether "some" is in the grammatical (surface) subject or object of the sentence.

There is another reason for investigating these sentences. A traditional problem in the psychology of reasoning is to determine the influence of linguistic form upon judgements of validity (cf. Woodworth and Sells, 1935; Sells, 1936). The experiments typically utilize syllogisms with singly-quantified sentences; but inferences may also be made with doubly-quantified sentences and these, too, may be influenced by linguistic form. Experiments could utilize either the unambiguous but stilted jargon of the logician ("For any man, there exists a woman such that the man knows the woman") or the idiomatic but ambiguous sentences of everyday discourse ("Every man knows some woman"). What, in fact, is needed is a preliminary study of the idiomatic material, since its very ambiguity may be a significant factor in reasoning. The present experiment was intended as a preliminary to a further study of inference.

Method

Task

Each subject was presented with a series of sentences. For each one, ten diagrams—representing different states of affairs—had to be classified as truthfully or falsely described by the sentence. The diagrams were chosen so that their classification would elucidate the subjects' intepretations of the sentences.

Design

Each subject was his own control and received the eight different forms of sentence. In order to reduce residual effects from one item to the next, each of the sentences had a different lexical content. Such effects seemed likely to be greater for logical form than for lexical content, hence, as a procedural variable, a series of 24 counterbalanced orders of presentation was derived from three 8×8 Williams' squares (cf. Edwards, 1963, p. 275). A separate order for the lexical material was assigned to each Williams' square; this provides only a crude control for effects associated with the lexical material, but it does provide an adequate control for any interaction between logical form and lexical content. The order of presentation of the diagrams was randomly determined for every trial.

Materials

The eight logical forms were those of sentences (1) to (8) except that the words in parentheses were omitted. The universal quantifier differs between the affirmative and negative sentences. In a pilot study, the use of "any" gave rise to a peculiar difficulty especially with the affirmative sentences. Subjects tended to regard a sentence like "Any medicine cures some disease" as true if a single medicine, chosen at random by the subject, cured some disease. Thus, the truth of the sentence depended upon "the luck of the draw." "Any" was accordingly used only where there was no alternative, that is, in the negative sentences, since "Some medicine does not cure *any* disease" differs in meaning to "Some medicine does not cure *every* disease."

The lexical materials are stated below in the same logical form throughout:

(a) Every man knows some woman.
(b) Every car overtakes some bus.
(c) Every job requires some skill.
(d) Every child loves some toy.
(e) Every brother hates some sister.
(f) Every liquid dissolves some solid.
(g) Every medicine cures some disease.
(h) Every animal possesses some instinct.

These materials were selected so as to vary the types of noun (e.g. human, abstract, etc.) and the reversibility of the sentences, i.e. whether the two nouns could be interchanged without producing a semantic anomaly (cf. Slobin, 1966).

The diagrams consisted of 3 × 3 matrices with each cell containing either a "1" or a "0": a typical matrix is shown in Figure 1. The ten matrices are shown in Table II. To understand the way the matrices have to be interpreted, imagine that they are paired with the sentence "Some woman is known by every man." Each row in the matrices then represents a man, and each column represents a woman. A "1" indicates that the man in whose row it is *knows* the woman in whose column it is. A "0" indicates that the man does *not* know

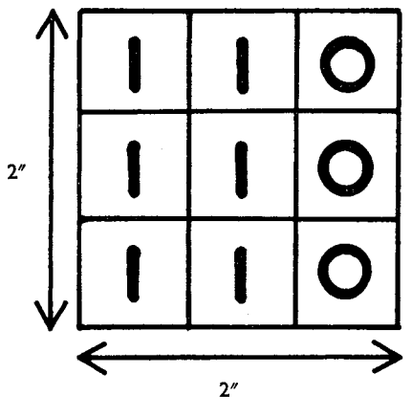

FIGURE 1. A typical matrix diagram.

the woman. Thus, the situation depicted in, say, matrix (8) is likely to be classified as truthfully described by the above sentence.

The choice of the particular ten matrices was based on two grounds. First, they were chosen as a representative sample from the complete set of such matrices, ignoring rotations or other transformations which had no effect upon how the matrices ought to be classified. Second, they were chosen so that the likely interpretations of sentences would be clearly reflected in the *pattern* of the subjects' choices. Three pairs of matrices, (3) and (8), (4) and (7), and (5) and (9), were chosen so that the logical classification would be the same for both members of the pair. These mutually redundant pairs provide a simple test of whether an interpretation is within the quantificational calculus.

The rows of the matrices always represented the logical (deep structure) subject and the columns the logical object of the sentences. This was likely to enhance any effect due to voice, but it was nevertheless left uncontrolled so as to minimize the difficulty of the task. To help subjects to identify rows and columns, a large "backing" card (9 in. × 6 in.) on

which there was an appropriately labelled blank matrix was on view throughout the classification. Eight backing cards were prepared: one for each set of lexical material, with the labels on the rows and columns typed in capitals.

Each of the 64 sentences (8 logical forms × 8 lexical contents) was typed on a plain 5 in × 3 in. card. The matrices, 2 in. × 2 in., were drawn in heavy ink at one end of a similar card, so that the subject could hold a card in his hand and clearly see the matrix.

Predictions

The nature of the predictions was slightly unusual in so far as there were two levels within them. Table II gives what will be termed the *privileged* classifications of the matrices. They rest on the assumption that subjects will give each sentence its privileged interpretation and

TABLE II

Ten matrix diagrams and the privileged classifications for the basic quantified relations

	1	2	3	4	5	6	7	8	9	10
	000 000 000	100 000 000	100 100 100	100 010 001	111 000 000	111 100 100	110 101 011	110 110 110	111 111 000	111 111 111
1. Every man knows some woman	0	0	1	1	0	1	1	1	0	1
2. Some woman is known by every man	0	0	1	0	0	1	0	1	0	1
3. Every woman is known by some man	0	0	0	1	1	1	1	0	1	1
4. Some man knows every woman	0	0	0	0	1	1	0	0	1	1
5. Any man does not know some woman	1	1	1	1	0	0	1	1	0	0
6. Some woman is not known by any man	1	1	1	0	0	0	0	1	0	0
7. Any woman is not known by some man	1	1	0	1	1	0	1	0	1	0
8. Some man does not know any woman	1	1	0	0	1	0	0	0	1	0
9. Every man knows every woman	0	0	0	0	0	0	0	0	0	1
10. No woman is known by any man	1	0	0	0	0	0	0	0	0	0
11. Some man knows some woman	0	1	1	1	1	1	1	1	1	1
12. Some woman is not known by every man	1	1	1	1	1	1	1	1	1	0

Note: Each row of a matrix represents a man, and each column represents a woman. A "1" under a matrix indicates that the matrix is classified as truthfully described, a "0" indicates that it is classified as falsely described. For convenience, the privileged classifications for sentences 9 to 12, not actually used in the experiment, have been stated.

then classify the matrices in a strictly logical fashion. These predicted patterns of classification may be summarized in the following way:

Sentences	*Matrices truthfully described*	*Matrices falsely described*
(1)	At least one "1" in every row.	At least one row of "0's."
(2)	At least one column of "1's."	At least one "0" in every column.
(3)	At least one "1" in every column.	At least one column of "0's,"
(4)	At least one row of "1's,"	At least one "0" in every row.
(5)	At least one "0" in every row.	At least one row of "1's".
(6)	At least one column of "0's".	At least one "1" in every column.
(7)	At least one "0" in every column.	At least one column of "1's."·
(8)	At least one row of "0's."	At least one "1" in every row.

It is clear that subjects can depart from the privileged classifications in a number of ways: they may produce the unprivileged classification (i.e. the one appropriate to the correlated sentence of the opposite voice), or a classification which is neither privileged nor unprivileged although still within the quantificational calculus (some Boolean function of the patterns in Table II), or finally a classification which is outside the quantificational calculus altogether.

Although subjects were expected to produce the privileged classifications, they were not expected to perform in every respect like trained logicians. Hence, a series of lower level predictions were made concerning departures from the privileged classifications: certain aspects of the sentences would cause difficulty, i.e. longer classification times and departures from the privileged classifications. It was predicted (i) that negatives would cause more difficulty than affirmatives. Negatives customarily cause difficulty (Wason, 1959, 1961) unless they occur in plausible contexts (Wason, 1965). It was also predicted (ii) that passives would cause more difficulty than actives, although this would be less than the effect caused by negatives (cf. McMahon, 1963; Gough, 1965; Slobin, 1966). Finally, it was predicted (iii) that the word order of the quantifiers would have an effect. The privileged interpretation should be easier to make when "some" is in the grammatical subject than when it is in the grammatical object. The argument underlying this prediction is that when "some" occurs in the object, it is taken as "some or other" almost by default, i.e. "some" is *not* in the subject therefore it does not mean "some in particular". Accordingly, this should lead to a greater difficulty in classifying the matrices.

Subjects

The subjects were 24 first-year undergraduates (14 male, 10 female) in the Department of Psychology, University College London. They were native-speakers of English but they were not familiar with the quantificational calculus.

Procedure

The subjects were allocated to a particular combination of logical and lexical material, and tested individually.

The subject sat at the end of a table which was screened off from the experimenter's part of the table. The experimenter read the instructions to the subject. These explained that the task was to determine what situations were truthfully (and falsely) described by a series of sentences. Each situation would be depicted by a diagram. A matrix was then introduced and the way it was to be interpreted was described in detail. The classification procedure was explained, and the subject was told that he could not ask any questions after the backing card for a sentence had been described. The subject was also told that he would be timed but that this must not disturb him: "I don't want you to race blindly through the task. Just imagine that somebody else has said the sentence to you, make up your mind what you think it means, and then make your classification. Make sure that your classification truly represents your considered opinion about the meaning of the sentence." Finally,

the subject was warned not to let his judgements be influenced by whether he thought the sentences were *really* true (or false).

The experimenter produced the appropriate backing card and the matrices, and described the lexical content of the sentence. The stopwatch was started as soon as the sentence was placed in front of the subject; it was stopped as soon as the last card was classified. The subjects were allowed to change their classifications, and the times recorded include intervals taken up by this. Between trials the experimenter recorded the time and the classifications, and re-ordered the matrices for the next trial, all of which took up an inter-trial interval of about 25 sec.

Results

Classifications

The proportion of subjects making the privileged, unprivileged, and other classifications for each form of sentence is shown in Figure 2. There was no reliable difference in performance with the different lexical materials and no

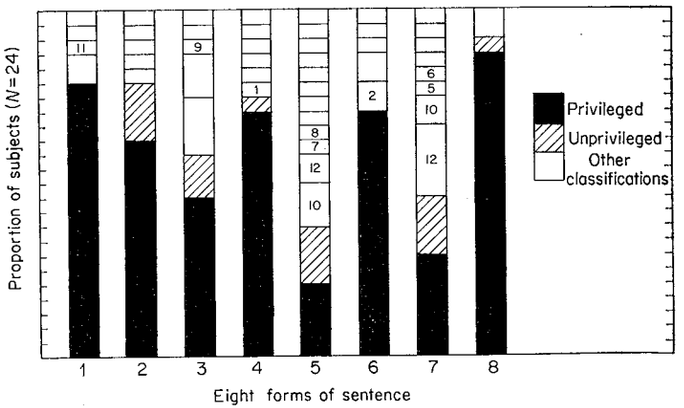

FIGURE 2. The proportions of subjects making the privileged, unprivileged, and other classifications for each form of sentence. (A number in a column indicates that the classification was privileged for the corresponding sentence e.g. 3 subjects gave sentence 5 the privileged interpretation of sentence 10.)

interaction between them and the logical forms, hence the analysis was on pooled data. The modal classification for each of the eight logical types was the predicted privileged one. The average number of privileged classifications per subject was 4·7 (out of a maximum of 8); since the probability of a given classification by chance is less than one in a thousand, it is evident that there was a very reliable bias in favour of the predicted classifications.

Since a major concern was whether the classifications were privileged or unprivileged, each classification was scored with respect to both of these interpretations. The higher score was taken as an index of which interpretation had been made. This made it possible to take all the data into account and to assign to each subject a number, ranging from +8 to −8, as a function of the degree to which he made the privileged interpretations. There was an overall mean of +5·2, and all 24 subjects had a positive score, which is highly significant on a sign test ($P = 0{\cdot}5^{24}$).

Departures from the privileged classifications

The maximum number of departures from the privileged classification which could be made on any trial was ten, since there were ten matrices to be classified. The mean number of such departures for each of the eight forms of sentence is shown in Table III, along with the classification times. An analysis of variance ($2 \times 2 \times 2$ fixed factors with repeated measures) indicated that both polarity and

TABLE III

Mean number of departures from the privileged classifications and mean classification times for the eight forms of sentence

	Affirmative				Negative				
	Subject		Object		Subject		Object		
	Active	Passive	Active	Passive	Active	Passive	Active	Passive	
Sentence no.	(4)	(2)	(1)	(3)	(8)	(6)	(5)	(7)	Overall
Mean departures from privileged classifications	0·8	0·9	0·4	1·1	0·3	0·9	2·4	2·3	1·1
Mean classification times (sec.)	40·2	44·6	44·5	52·4	50·7	48·0	64·5	74·4	52·4

Note: the word order factor, indicated by "subject" and "object", refers to whether "some" was in the grammatical subject or object of the sentence. The maximum possible number of departures from the privileged classification on any trial was 10. The sentence numbers quoted are those used in Table I.

word order produced reliable differences in the predicted direction, with $F_{1,161}$ ratios of 11·2 ($P < 0{\cdot}01$) and 16·5 ($P < 0{\cdot}001$), respectively. However, there was also a significant interaction between these two factors ($F_{1,161} = 19{\cdot}1$, $P < 0{\cdot}001$). Neither voice nor any of the remaining interactions yielded significant effects. Departures from the privileged classifications showed no signs of diminishing with practice.

If the subjects had performed as predicted in Table II, they would have classified an average of 5 out of 10 matrices as true on each trial. In fact, the overall mean was 4·5 matrices classified as true: 18 subjects had averages less than 5, three subjects had averages of greater than 5, and the remaining three subjects had averages of exactly 5. Hence, there was a significant bias ($P < 0{\cdot}002$ on a sign test) in favour of classifying a matrix as falsely described by the sentence. Performance did not differ reliably between matrices: they all tended to be classified as true too few times.

Classification times

The mean classification times, from the moment the sentence was presented until the classification was complete, are shown for the eight forms of sentence in Table III. An analysis of variance indicated that there were significant effects due to polarity ($F_{1,161} = 9{\cdot}2$, $P < 0{\cdot}01$) and word order ($F_{1,161} = 8{\cdot}1$, $P < 0{\cdot}01$). Neither voice nor any interactions yielded reliable effects, though Table III indicates a

trend in the direction of an interaction between polarity and word order. There was a marked learning effect in the classification times of all eight forms of sentence.

Qualitative results

Relatively few classifications were outside the quantificational calculus, i.e. involved an inconsistent classification of a mutually redundant pair of matrices. Sixteen subjects were responsible for a total of 31 such classifications (16·1 per cent of all classifications). This percentage, however, constitutes just under half of those interpretations which were neither privileged nor unprivileged. It was often the case that a plausible account could be given for the interpretations outside the quantificational calculus. For example, three subjects presented with sentence (3) of the form "Every woman is known by some man" produced the privileged classification except that they classified matrix (9) as falsely described by the sentence. It seems they had taken the some *or other* interpretation so much to heart that they refused to countenance the regularity of two particular men knowing all the women. Conversely, with sentence (4) of the form "Some man knows every woman," one subject took the some *in particular* interpretation so strictly that his classification represents one particular man knowing every woman and no other man knowing any women.

The interpretations which were within the quantificational calculus but neither privileged nor unprivileged are harder to explain. Some of them seem to be no more than mistakes, e.g. (1) "Every man knows some woman" being interpreted as (11) "Some man knows some woman." Others, particularly those involving Boolean combinations of the basic sentences, seem to have some obscure motivation, e.g. four subjects interpreted (3) "Every woman is known by some man" to imply in addition that (1) "Every man knows some woman." This is, perhaps, a case of subjects' judgements being influenced by the real world. Figure 2 shows that sentences (5) and (7) tended to receive a variety of alternative interpretations; as we shall see, these were *not* primarily due to misinterpretations of the sentences.

Subjects rarely interpreted "some" to imply "not all." Thus, for example, "Some medicine cures every disease" was deemed quite consistent with the situation in which every medicine cures every disease. This *logical* performance is in contrast to the view of Chapman and Chapman (1959) that, with singly quantified sentences, "Some A is B" is usually taken to imply "Some A is not B." Yet in ordinary discourse "some" often does imply "not all"; thus it may be that this implication is less strong with doubly quantified sentences. A related finding was that "some N"—where N stands for a singular noun—was rarely interpreted to mean just a single entity. One such case has been mentioned, there were only two others.

Introspective reports

No subject spontaneously complained about the ambiguity of the sentences, though it was evident that at least ten subjects had noticed the ambiguity of "some." A number of subjects were able to state the features of the sentences which had caused them difficulty. These reports varied from general statements referring to "the negative sentences" or "the sentences with 'any' and 'some'" to the more

sophisticated reports of the five subjects who said that "some" could be either singular or plural. This distinction was made even when it was clear that the subject had never interpreted "some" as singular. It represents perhaps the nearest that subjects could get to stating the distinction between some *in particular* and some *or other*.

Only two subjects mentioned the passive voice; one subject said that he was surprised because some of the sentences could have been more simply expressed in the active voice, the other subject had "switched the sentences round when they were passives" though, in fact, this subject did *not* interpret the passives as synonymous with their active correlates. There were just seven occasions (out of 96) on which an active and correlative passive received the same interpretation.

Discussion

The task which subjects had to perform in the present experiment was difficult. It involved interpreting logically complex sentences with respect to a series of rather abstract situations. Nevertheless, the subjects consistently made the privileged classifications, with active and correlative passive sentences receiving different interpretations. The departures from the privileged classifications indicate that, as predicted, there was more of a consensus about the meaning of affirmative than negative sentences. There was, again as predicted, more of a consensus when "some" was in the grammatical subject than when it was in the grammatical object. Unfortunately for the assumptions on which these predictions were based, there was an unexpected interaction between the two factors: word order had an effect on the departures from the privileged classifications only in the case of negative sentences (cf. Table III).

The main question which the interaction raises concerns sentences (5) and (7), e.g.:

(5) Any child does not love some toy.

(7) Any toy is not loved by some child.

Why did these sentences receive more diverse interpretations than any others including those to which they are related by voice? One possibility is that these sentences are slightly anomalous, and one might even suppose that they are meaningless. Yet the answer, suggested by the subjects' actual classifications, is that they have more *possible* interpretations. This extra and unforeseen ambiguity is due to two factors.

First, the word "some" in a predicate with a negative verb-phrase has an additional ambiguity. So far, we have been considering the word pronounced [sʌm] which tends to occur with count nouns. There is another word, pronounced [sm̩], which tends to occur with mass nouns (cf. Bolinger, 1960). The difference between these two words is important in negative sentences: compare "John doesn't like some ([sʌm]) people" with "John doesn't want some ([sm̩]) butter." The latter is logically equivalent to "John wants no butter whatsoever" but the former is not equivalent to "John likes no people whatsoever." A written sentence like

"John doesn't want some pens" may thus receive any of three interpretations: John wants no pens whatsoever, John doesn't want some particular pens, or John doesn't want some pens or other (i.e. he doesn't want just any or every pen).

Second, sentences with a negative verb-phrase and a realization of the universal quantifier in their subject are ambiguous. For example, "All women do not lie" may mean either that lies are not told by *any* woman (no woman lies) or that lies are not told by *every* woman (not all women lie). This ambiguity about the scope of negation occurs whether the verb is transitive or intransitive, whether it is active or passive, and whether the quantifier is "every," "any" or "all." It even occurs in attributive descriptions like "All the square is not red" (Wason, personal communication).

Combining the two sources of ambiguity yields six possible interpretations for sentences (5) and (7). They may both receive any of the following interpretations, logically equivalent to those predicted for sentences (5), (6), (7), (8), (10) and (12):

(5) Some toy or other is not loved by any child.

(6) Some toy in particular is not loved by any child.

(10) No toy whatsoever is loved by any child.

(8) Some toy or other is not loved by every child.

(12) Some toy in particular is not loved by every child.

(7) No toy whatsoever is loved by every child.

It is a moot point whether these interpretations are possible for the voice-correlated sentences (6) and (8):

(6) Some toy is not loved by any child.

(8) Some child does not love any toy.

On balance, it would seem that they are possible: "Some ([sm̩]) child *isn't* sick" may be interpreted as "No child is sick," and "John isn't loved by any child" may be interpreted as "John isn't loved by *just* any (every) child." Hence, theoretically it would seem that sentences (5), (6), (7) and (8) are all ambiguous in the same way.

This startling consequence is not borne out in actual performance. Sentences (6) and (8) are interpreted very much as though they were unaffected by the extra sources of ambiguity and are clearly differentiated one from the other. Word order is crucial: "Some" at the beginning of a negative sentence is even less likely to elicit the interpretation "none" than the interpretation "some or other"; "any" at the end of a negative sentence is more likely to elicit the interpretation "none" than the interpretation "not all." Figure 2 shows that the most likely interpretations for sentences (5) and (7) are their respective privileged and unprivileged interpretations, though the other possibilities do all occur. This suggests that sentences like "Any man does not know some woman" tend to receive interpretations consistent with "Some woman is not known by *any* man," whereas "Any woman is not known by some man" tends to receive interpretations consistent with "Some woman is not known by *every* man." This is an effect on meaning which occurs in performance and which is due to voice and *not* to word-order changes brought about by voice (cf.

Johnson-Laird, 1968*b*). It seems that the scope of negation tends to be minimized with respect to the "actor," but maximized with respect to the "acted-upon."

There are a number of possible explanations for the differences in the classification times. It is possible that they are due to the pattern recognition aspects of the task, although the majority of subjects adopted no such explicit strategy. An informal study in which four subjects classified the matrices according to specified *patterns* showed that the average times were 8·0 sec. for "at least one column of "o's"" and 9·4 sec. for "at least one 'I' in every row." The average times for the sentences were all over 40 sec. It therefore seems unlikely that the pattern recognition aspects of the task were important. Since there was no reliable interaction between polarity and word order, it is possible that these variables had their effects on the classification times for the predicted reasons. There is, however, a strong likelihood that it was the ambiguity of the sentences which was crucial. Recent studies (MacKay, 1966; MacKay and Bever, 1967) have indicated that the more ambiguous the sentence or phrase, the longer it takes to interpret or to complete.

It seems that the negation of falsity is not psychologically equivalent to truth. The reliable bias towards classifying matrices as falsely described indicates that when subjects were in doubt, they chose falsity as the "safer" classification. When neither the privileged nor the unprivileged classification was made, there was a tendency to go outside the quantificational calculus, e.g. one and only one man does not know any woman. But, often this could be explained as a zealous, if naïve, attempt to distinguish some *or other* from some *in particular*.

The fact that both privileged and unprivileged interpretations occurred demonstrates both surface and deep-structure processing of the sentences. Clark and Begun (1968) have shown both levels of processing operating in tasks where subjects had to detect or correct semantic anomalies. Katz and Postal (1964) proposed that, for models of competence, all semantic interpretation is performed on deep structure, i.e. grammatical transformations do not change meaning. It might therefore be supposed that, in actual performance, the listener needs only to extract the deep structure in order to understand the sentence. The assignment of surface structure would occur only in so far as it was necessary for the assignment of deep structure and, more importantly, it would be held only temporarily in immediate memory. This is consistent with the fact that individuals remember sense not syntax. But it is this view which the present experiment casts some doubt upon: left-to-right processing *is* important because it biases the interpretative machinery. Surface structure provides clues to deep structure, but these clues—and in particular word order—may point to only one interpretation of an ambiguous sentence. There is one difficulty with this argument, due to the lack of an account of the semantics of quantifiers. It is possible that the particular ways in which quantifiers are introduced into deep structures, or changed when deep structures are transformed into surface structures, would yield radical differences in the deep structures of voice-correlated sentences. It is hoped that this study of performance has demonstrated the need for a linguistic account of the semantics of quantifiers.

The author is very much indebted to Dr. P. C. Wason for his inestimable advice and encouragement, and for a critical reading of an earlier version of this paper.

References

BOLINGER, D. (1960). Linguistic science and linguistic engineering. *Word*, **16**, 374–91.

CHAPMAN, L. J. and CHAPMAN, J. P. (1959). Atmosphere effect re-examined. *J. exp. Pyschol.* **58**, 220–6.

CLARK, H. and BEGUN, J. S. (1968). The use of syntax in understanding sentences. *Br. J. Psychol.* **59**, 219–29.

CHOMSKY, N. (1957). *Syntactic Structures*. The Hague: Mouton.

CHOMSKY, N. (1965). *Aspects of the Theory of Syntax*. Cambridge, Mass.: M.I.T.

EDWARDS, A. E. (1963). *Experimental Design in Psychological Research*. Revised edition. London: Holt, Rinehart and Winston.

GOUGH, P. B. (1965). Grammatical transformations and speed of understanding. *J. verb. Learn. verb. Behav.* **4**, 107–11.

JOHNSON-LAIRD, P. N. (1968*a*). The interpretation of the passive voice. *Q. Jl exp. Psychol.* **20**, 69–73.

JOHNSON-LAIRD, P. N. (1968*b*). The choice of the passive voice in a communicative task. *Br. J. Psychol.* **59**, 7–15.

KATZ, J. J. and MARTIN, E. (1967). The synonymy of actives and passives. *Philos. Rev.* **76**, 476–91.

KATZ, J. J. and POSTAL, P. M. (1964). *An Integrated Theory of Linguistic Descriptions*. Cambridge, Mass.: M.I.T.

MACKAY, D. G. (1966). To end ambiguous sentences. *Percept. Psychophys.* **1**, 426–36.

MACKAY, D. G. and BEVER, T. G. (1967). In search of ambiguity. *Percept. Psychophys.* **2**, 193–200.

MCMAHON, L. E. (1963). *Grammatical Analysis as Part of Understanding a Sentence*. Unpublished doctoral thesis, Harvard University.

SELLS, S. B. (1936). The atmosphere effect: an experimental study of reasoning. *Arch. Psychol.* **29**, 3–72.

SLOBIN, D. I. (1966). Grammatical transformations and sentence comprehension in childhood and adulthood. *J. verb. Learn. verb. Behav.* **5**, 219–27.

SUPPES, P. (1957). *Introduction to Logic*. London: Van Nostrand.

WASON, P. C. (1959). Processing of positive and negative information. *Q. Jl exp. Psychol.* **11**, 92–107.

WASON, P. C. (1961). Response to affirmative and negative binary statements. *Br. J. Psychol.* **52**, 133–42.

WASON, P. C. (1965). The contexts of plausible denial. *J. verb. Learn. verb. Behav.* **4**, 7–11.

WOODWORTH, R. S. and SELLS, S. B. (1935). An atmosphere effect in formal syllogistic reasoning. *J. exp. Psychol.* **18**, 451–60.

ZIFF, P. (1966). The nonsynonymy of active and passive sentences. *Philos. Rev.* **75**, 226–32.

Received 10 *May* 1968