Psycholinguistic Operations in Sentence Comprehension: Implications for Aphasiology

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Prologue

Most sciences began when inquisitive men attempted to infer the nature of mechanisms underlying regularities they observed in nature. Some of them turned out to be correct, when modern instrumentation and mathematics led to observation and precise description of the mechanisms.

Introduction

The boy was pushing the girl.
The girl kicked the boy.
The boy was kicked by the girl.
The boy is not pushing the girl.

Psycholinguistic studies have revealed that aphasics' comprehension of the first two sentences, which are active affirmatives, was easier than the third sentence, which is a passive. The passive was easier than the fourth sentence, which is a negative. Since the same relative difficulty was found with normal adults, aphasics were assumed to comprehend with the same psycholinguistic mechanism as normals but at a reduced efficiency. A few aphasiologists concluded that diagnosis and retraining of sentence comprehension should be sensitive to syntactic complexity. Though the conclusions may be useful to some extent, they were based on an inadequate model of the mechanism underlying the sentence hierarchy.

The first part of this paper will show why this model was unsuccessful and thereby introduce you to how a comprehension mechanism might be inferred from a hierarchy of sentence difficulty. Then, I shall point out factors in addition to syntax that should be considered in an examination as well as a theory of sentence

comprehension. Finally, I shall describe one example of the information processing models that have replaced the inadequate model. This model building provides us with a framework of normal processing that may help us determine why some aphasics have certain comprehension difficulties. There will be some difficulties in applying the new models to studies of aphasia, but I will not have time to discuss these problems here.

The Transformation Model

Since we need to know the nature of normal psycholinguistic processes to understand disturbances of these processes, a few aphasiologists have been sifting carefully through the bits and pieces of psycholinguistic prospects. Some of these aphasiologists looked to the transformation model of sentence comprehension for interpreting their observations of aphasics. In the attempt to endow Chomsky's transformational grammar with some form of psychological function, each transformational rule was thought to be a mental operation used to produce and comprehend sentences. In order to test this theory, each operation was assumed to take time with the time per operation being additive. Therefore, the number of transformations in a sentence should determine the time to comprehend it.

For an illustration of how the transformation model works, let us begin with Figure 1. This simple active affirmative sentence, which subjects have heard in typical comprehension studies, is called the surface structure. Comprehension was supposed to involve a process of stripping transformations from the surface structure to arrive at the deep structure, which is the linguistic representation of sentence meaning. The so-called reverse application of transformational rules, for this sentence, is a direct process basic to comprehending all types of sentences. The time for stripping away surface verb form and meaningless articles will be called Base Time, denoted by the symbol t.

Shown in Figure 2, the reverse application of transformational operations for the negative sentence would involve removing the word not as one operation taking time X and, again, the standard base time operation t. Assuming that time per operation is additive, the negative should take more time to comprehend than the active affirmative.

Operations in comprehending the passive (see Figure 3) would include removing the word by, taking time y, and reversing the subject and object, taking time z, in addition to base time t. If operations x in the negative and y and z in the passive each take the same time, comprehending the passive with one more operation should take longer than the negative.

The transformation model, shown in Figures 1-3, was tested by measuring the time taken to comprehend these sentence types, and the model predicted the hierarchy of difficulty shown in Figure 4.

Active affirmatives should have taken the least amount of time, followed by negatives, passives, and passive negatives. You may recall from the sentences introducing this paper that this was not the actual hierarchy of difficulty found in studies of normals and aphasics. Figure 5 will refresh your memory of the actual hierarchy. The transformation model does not predict and, therefore, cannot account for the order of difficulty in this figure.

In the pioneering comprehension experiments, negatives took more time than passives. Slobin (1966) recognized this problem in his study and suggested that semantic factors, in addition to syntactic features, must be incorporated in a model of the comprehension mechanism. I must conclude that this applies to diagnostic testing, as well.

Even if some of the assumptions about time per operation are modified other aspects of the initial data could not be explained by the transformation model. Before I get into these crucial problems, I need to describe briefly the testing procedure, called the sentence verification technique. It was used to test the reverse transformation model and by Levy (1968) and Levy and Holland (1971) to study aphasics. It is being used extensively to test the information processing model that I shall describe later. Usually, the experimenter presents a sentence orally or in print followed by a picture that either does or does not correspond with the sentence. The subject presses one of two buttons indicating the sentence is true or false relative to the picture. Response time is measured between the onset of the picture and pressing the button. In the early studies, responding true or false was just a way of forcing the subject to comprehend various sentence types. However, subjects showed consistent time differences depending on the truth value of the sentence. The transformation model could not handle this, since its operations had to be the same for a given true or false syntactic structure. Even more baffling was the finding in experiments by Gough (1966) and Slobin that true negatives took more time than false negatives. There were no mechanisms to account for this.

Other research with normal adults showed that variations of semantic function made negatives easier than passives, sometimes, and passives easier than negatives, at other times (Greene, 1970). When the picture in one verification task emphasized the logical object of the action, the passive sentence was easier than the simple active (Olson and Filby, 1972). A model of normal comprehension processes should account for truth value, semantic function, and perceptual context. I must conclude that this applies to diagnostic testing, as well.

The Information Processing Model

The information processing model contains a small set of

basic mental operations that predict relative response time in different well-defined situations. Presently, it is used to account for performance on sentence verification tasks. The model easily accounts for seemingly contradictory results, because it responds to differences in semantic function and context. Today, I can give you only a general idea of how this model works. I shall focus on the comprehension of negatives and affirmatives with reference to the major features of one experiment. Before getting into that, Figure 6 shows how sentence types and truth value combine to form the four basic conditions in these studies. These examples are similar to conditions in one study by Just and Carpenter (1971). The typical study compares average response time to true affirmatives, false affirmatives, true negatives, and false negatives.

The information processing model retains the fundamental assumption that mental operations take time and the times for the separate processes are additive. That is, differences in response time indicate differences in the number of operations. Three features in the present example of the model should be kept in mind. The first is a response index which may be thought of as a set to respond a certain way. The sample model developed by Clark and Chase (1972) assumes the response index is set at True unless something in the referent suggests otherwise. The second and third features are the two principal stages in the comprehension process. In the initial stage, the sentence and the picture are coded. In the second stage, the sentence code and the picture code are compared. If there is a mismatch between codes, the response index must change; and this operation takes time.

Table I shows the true affirmative condition in Clark and Chase's first experiment. From top to bottom, the Table refers to the principal stages of the process, the response index, and the components of time to comprehend. The model specifies that, in the first stage, the sentence and picture are coded in terms of a proposition. The same format for the two codings is assumed necessary to facilitate comparison. Stage II compares corresponding constituents between each coding. In the true affirmative condition, the constituents match as indicated by the plus (+). Therefore, the response index remains set at True. The average response time for this condition is base time t, which includes factors common to all conditions.

```
                                            *
    S:  The star is above the plus.     +
    I        (star above plus)      (star above plus)
    II              +
    R:       T
    Time:    t
```

Table I. Mental operations in verifying true affirmative sentences (Clark and Chase, 1972).

Table II specifies the additional operation accounting for
the longer time needed to comprehend a false affirmative. To
determine this sentence is false, the subject finds a mismatch
between the two codings, represented by the minus (-) sign, and
changes the response index to False. This additional mental
operation, represented by the letter c takes up what Clark and
Chase called Verification Time.

```
                                           +
     S:  The star is above the plus. *
     I       (star above plus) (plus above star)
     II                  -
     R:  T               F
  Time:  t              +c
```

Table II. Mental operations in verifying false affirmative
sentences (Clark and Chase, 1972).

The same mental operations predict that false negatives
will be easier than true negatives. Table III shows the false
negative condition. Since the sentence is negative, it is coded
in a proposition that simply states: It is false that the star
is above the plus. Additional time to code the negative sentence
is designated by the letter b. In stage II, constituents always
are compared from the inner clause to the outer clause. In this
condition, the match of the inner or embedded clauses leaves
the response index at True. However, the outer or embedding clauses,
which code the sentence as negative and the picture as an implicit
affirmative, do not match. Therefore, the response index is
changed to False, taking time d. Operations b and d together
consume what is called Negation Time.

```
                                         *
     S:  The star isn't above the plus.  +
     I   false (star above plus) (star above plus)
     II     -              +
     R:  T                 F
  Time:  t      +b        +d
```

Table III. Mental operation in verifying false negative sentences
(Clark and Chase, 1972).

The true negative takes longer because it requires both Verifi-
cation Time and the two components of Negation Time. Table IV
shows the negative sentence coded as before taking time b. The

inner clauses do not match, changing the response index to <u>False</u>, taking time <u>c</u>. The outer clauses do not match, changing the response index back to <u>True</u>, taking time <u>d</u>.

```
                                          +
    S:  The star isn't above the plus.  *
    I   false (star above plus) (plus above star)
    II        -              +
    R:  T          F     T
  Time:  t      +b+c+d
```

Table IV. Mental operations in verifying true negative sentences (Clark and Chase, 1972).

The operations that take time beyond the base time include the extra coding operation and the response index change whenever a mismatch occurs.

The summary of these operations, shown in Table V, reflects the actual hierarchy of these conditions found in several studies of normals and in Levy's study of aphasics. The components of the total response time in each condition are shown. Clark and Chase subtracted mean response times of each condition from each other in order to estimate time for each mental operation. These operations account for the differences between truth values that Slobin and Gough found difficult to explain with the transformation model. This model fills the gap found by Levy with the transformation model as she concluded that the significant effects of truth value in her study provided little information about sentence comprehension.

```
          TA=t
          FA=t             +c
          FN=t       +b         +d
          TN=t       +b   +c   +d
```

Table V. Components of total response time in each of the four verification conditions (Clark and Chase, 1972).

Exceptions to this negation truth value hierarchy do occur, and they occur when the function of the negative or the perceptual context differ in a way that requires an adjustment of coding in Stage I. With Stage II comparisons carried out as shown here, the model predicts these exceptions.

In conclusion, the information processing model represents an advance in an area of knowledge that is essential to aphasiology.

It provides a framework for constructing tasks that may tell us why a certain difficulty arises and not just that there is a difficulty relative to other groups. The nature of impairment can be understood only with reference to some idea of what process is impaired. Unfortunately, it is sometimes hard to keep track of changes in psycholinguistics. Clark and Chase's idea already has been simplified by Carpenter and Just (1975) who rely on comparison operations to account for time differences.

Epilogue

Inferences about the mechanism underlying regular patterns of human response time might be compared with an early inference in the biological sciences. Over 100 years ago, Mendel had a notion that a living organism possesses a dominant particle and a recessive particle for each characteristic of that organism. His evidence came through the systematic pairing of hybrid pea plants by artificial insemination according to single well-defined plant characteristics. By observing the offspring, he inferred that the joining of a single particle from each parent was the only mechanism that could account for the characteristics of the offspring. Modern instrumentation showed Mendel had the right idea. Psycholinguistics seems to be at the same point that genetics was with Mendel. By comparing sentences with different well-defined characteristics and observing human response to them, scientists try to infer the nature of the underlying mechanism. Someday the relevant neuropsychological particles will be found when the appropriate instrumentation and mathematics are developed.

References

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Slobin, D.I., Grammatical transformations and sentence comprehension in childgood and adulthood. Journal of Verbal Learning and Verbal Behavior, 1966, 5, 219-227.
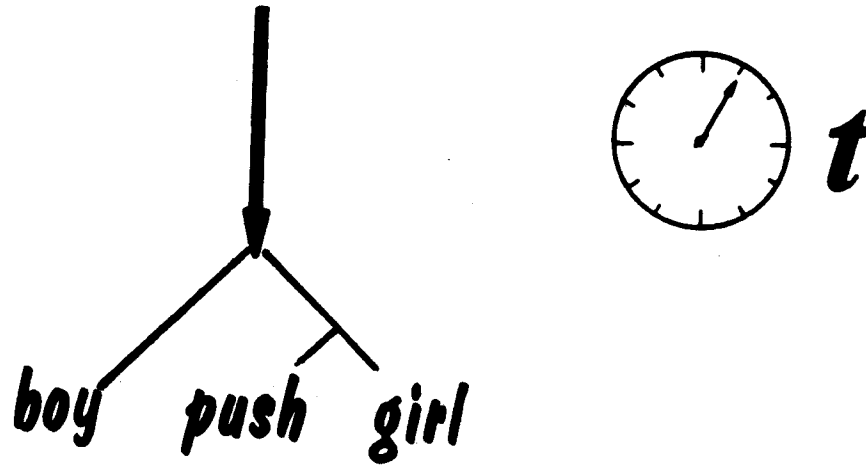
Figure I

Illustration of the reverse transformation operation taking
base time in comprehending an active affirmative sentence.
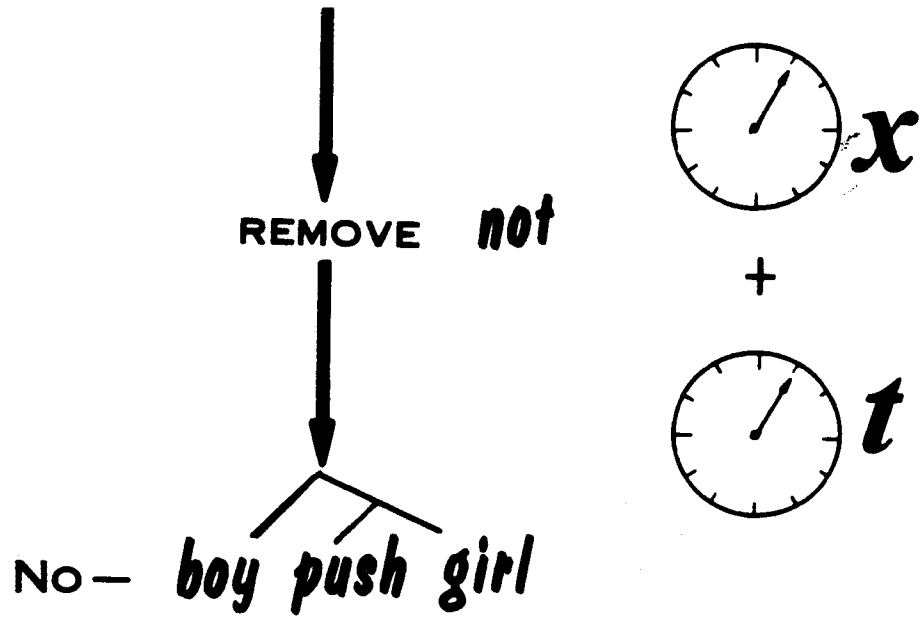
The boy is not pushing the girl.

REMOVE *not*

x
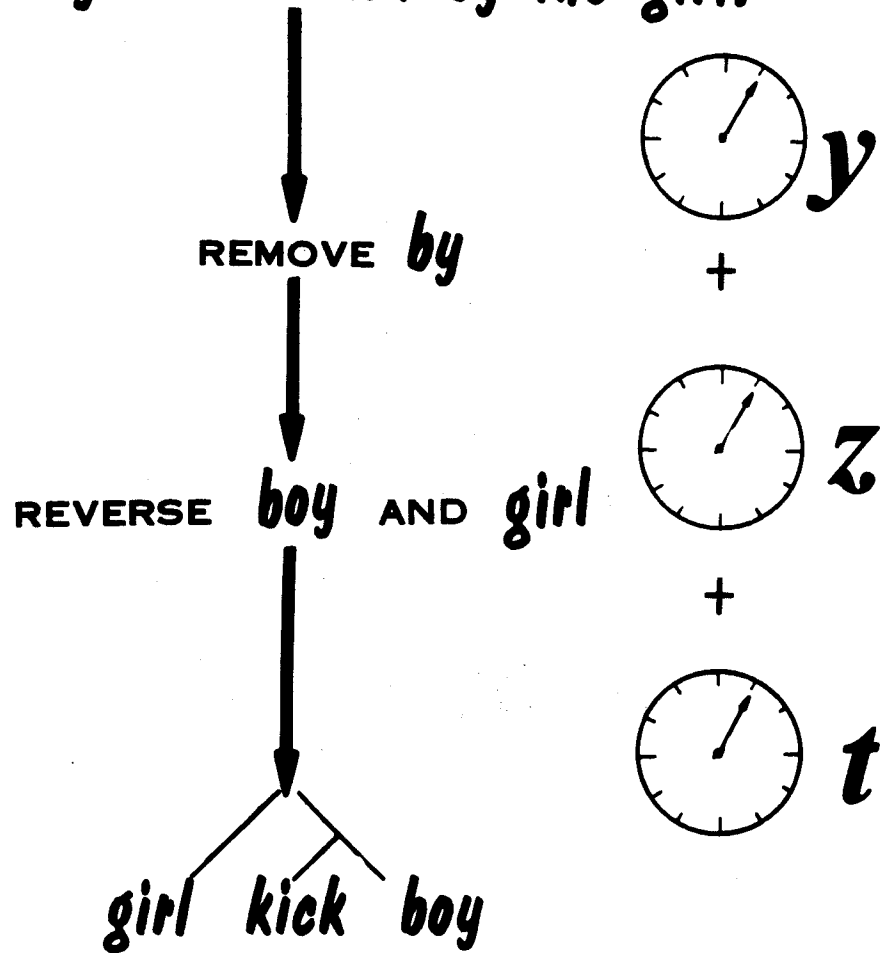
$+$

t

NO— *boy push girl*

Figure II

The reverse transformation operations in comprehending a
negative sentence.

The boy was kicked by the girl.

↓

REMOVE *by*

↓

REVERSE *boy* AND *girl*

↓

girl kick boy

y

+

z

+

t

Figure III

The reverse transformation operations in comprehending a passive sentence.

AA $= \bigodot_t$

Neg $= \bigodot_t + \bigodot_x$

Pass $= \bigodot_t + \bigodot_y + \bigodot_z$

Pass-Neg $= \bigodot_t + \bigodot_x + \bigodot_y + \bigodot_z$
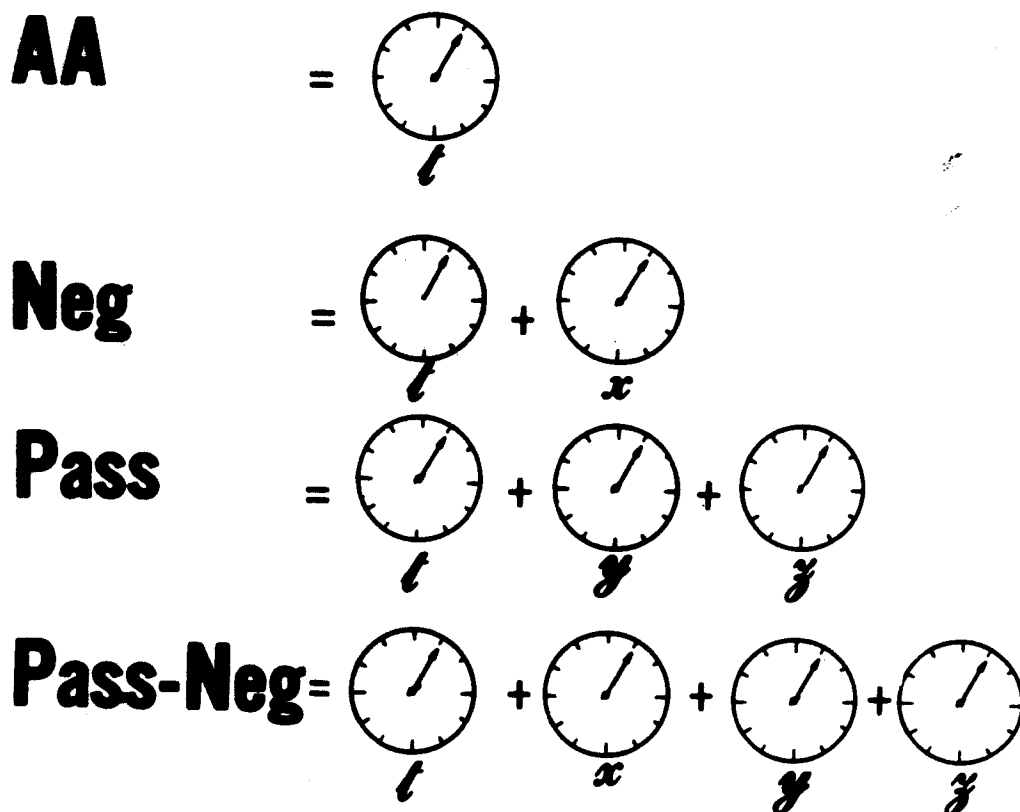
Figure IV

The hierarchy of difficulty in comprehending four sentence
types predicted by the transformation model. The hypothesized
times taken by each reverse transformation operation are repre-
sented.

AA =
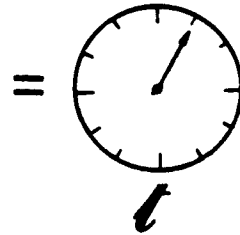
Pass = +
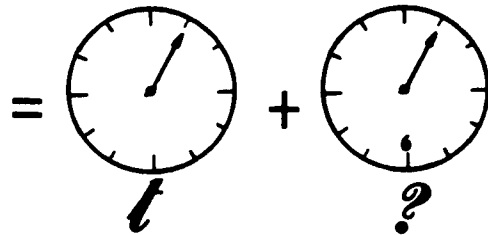
Neg = +
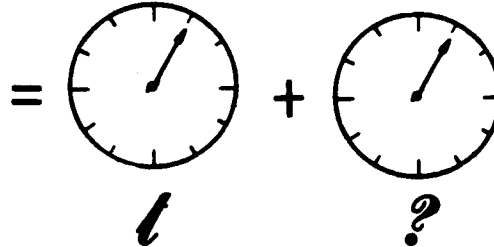
Pass-Neg = +
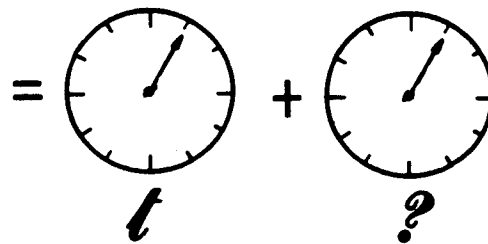
Figure V

The actual hierarchy of difficulty found in sentence verification
studies of normal and aphasic adults. This outcome cannot be
explained by a model of transformation operations, leaving an
explanation of the response time differences uncertain until
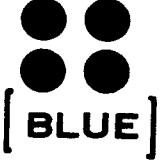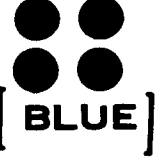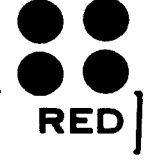a better model is proposed.

TA   *The dots are red*   [RED]

FA   *The dots are red*   [BLUE]

TN   *The dots are not red*   [BLUE]

FN   *The dots are not red*   [RED]

Figure VI

The four basic conditions in a sentence verification study of negation. Example derived from Just and Carpenter (1971).