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AUTHOR Dell, Gary S.
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ABSTRACT

In order to explore the effect of semantic organization on the comprehension of sentences, this research, based on the hypothesis that fully grammatical sentences would be processed more easily than anomalous sentences, depended on data provided by 20 paid college students serving in individual sessions. Each student listened to 30 tape-recorded sentences-15 fully grammatical and 15 anomalous--through one speaker of a stereo system, and pressed a finger key as rapidly as possible on presentation of a tape-recorded click (at 4, 5, 8, 10, or 12 seconds) through the second speaker in the silent period following each sentence. Students then repeated each sentence verbatim 20 seconds after its presentation to insure perception of both sentence and click. Analysis of variance for reaction times yielded a significant effect for semantic relations. Reaction times for anomalous sentences showed a strong linear downward trend, but those for grammatical sentences did not. Data support the hypothesis that the semantic organization of a sentence affects the ease with which it is processed. The effect of semantic organization seems to occur immediately after, not as, the full sentence is heard. (JM)

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Name of Principal Author: Gary S. Dell
Mailing Address: Department of Psychology; University of Toronto; Toronto, Ontario; Canada
Title of Paper: The role of semantics in sentence-processing
Authors and Institutions: Gary S. Dell, University of Toronto and Shel Feldman, Swarthmore College

Objectives

The purpose of this research was to explore the effect of semantic organization on the comprehension of sentences. Specifically, it was hypothesized that fully grammatical sentences would be processed more easily than sentences that are anomalous. This prediction follows directly from earlier studies of the effects of grammar upon performance, such as that of Miller and Isard, who found differences in recall of grammatical and anomalous sentences. None of the earlier research, however, has demonstrated within-sentence effects with methods that depend upon immediate responses, rather than upon memory capacity, selective recall, or logical ability. This study attempted to demonstrate the contemporaneous effect of semantic variables upon the processing of sentences.

Theoretical Framework

Any theory of language performance must specify the effects of grammatical variations upon sentence processing. Numerous studies of this problem have appeared since the advent of the Chomskian revolution in linguistics, but almost all involve performance separated from the initial processing of the linguistic materials. Typical studies have measured speed of recognizing specific transformations of sentences; capacity for recalling a sentence together with unrelated materials, as a function of transformations in the sentence; ability to paraphrase compound nominalizations; and so forth. But if grammatical rules are of critical importance in the very perception of sentences as they are heard or read, these studies are not completely germane; more immediate responses must be studied.

In some early studies, a click--a short burst of noise--was embedded in each of a set of compound sentences, using a two-channel tapedeck. Following presentation of each sentence, listeners were asked to specify where the click had occurred. It was found that subjects tended to move the clicks toward the clause break in these compound sentences, but the possibilities for the intrusion of selective recall, experimenter demand, and so forth in this procedure have led critics to question the results of these studies.

More recently, Holmes and Forster developed a novel variation on these click studies, which seems to avoid the problems cited. Furthermore, their method provides evidence of the effects of grammatical variations on sentence-processing contemporaneous with the initial perception of the sentence. In this procedure, the subjects press a key in response to the click, while listening to the sentence. Holmes and Forster found that finger-pressing reaction times were shorter for clicks embedded in clause breaks than for those embedded within individual clauses, incidentally validating the results of the earlier studies. They suggested that the results indicate a perceptual segmentation of the compound sentence at the break between the simple sentences it comprises. More broadly, this result indicates that sentence-processing does involve recourse to grammatical rules even during initial perception of the sentence.

If segmentation of the speech stream into sentences during initial perception can be demonstrated by this procedure, it may be asked immediately whether other levels of sentence-processing can also be demonstrated thereby. In particular, if reaction time to clicks is slower when some internal analyzer is occupied with parsing the incoming sentence (to speak loosely), variations in the load upon that analyzer might affect processing, and hence reaction time to clicks. Presumably, fully grammatical sentences should be more meaningful and more easily processed at the semantic level than anomalous sentences, hence reaction time to clicks in grammatical sentences should be shorter than to clicks in anomalous sentences.

In an earlier study, the present authors tested for the effect of sentence anomaly upon reaction time to clicks embedded at varying points in sentences, following the procedure of Holmes and Forster. No effect of this semantic variable was found. In itself, this result agrees with the results of earlier studies by others, including Holmes and Forster, in which no effects of within-clause variables have been demonstrated (as opposed to effects between the simple sentences of a compound). However, one set of strong results was noted, which lead to the present study.

The position of the click within the sentence was varied systematically, in this earlier study, from the first content word through the fifth. A linear downward trend in reaction times was anticipated, due to the effects of increasing readiness of the subjects as the click foreperiod was lengthened. Indeed, this linear effect did occur ($F = 12.78$; $df = 1/734$), but its effect was smaller than anticipated, and a large quadratic effect was found in the residual variance ($F = 21.28$; $df = 1/734$). The tendency was for both clicks early in the sentence and those late in the sentence to be associated with longer reaction times than those in the middle.

The pattern of these results might be explained as follows: Semantic processing is delayed until a sentence break is perceived, hence no difference between meaningful and nonmeaningful strings should be apparent in reaction time to clicks embedded within such strings. Memory, or the appropriate analyzer, is loaded with progressively more material as the sentence is read, but the sentence break nd reached. The effects of anticipation first outweigh, and then are swamped by, the effects of memory load; hence the quadratic time trend.

One derivation from this line of reasoning is that semantic processing must take place after the perception of the sentence break. Therefore, while no effect of sentence anomaly was found with clicks embedded within sentences, such an effect should be found when the click is embedded in the silence immediately following the presentation of the sentence.

Method

Each subject listened to 30 tape-recorded sentences through one speaker of a stereo system. Fifteen sentences were fully grammatical, and 15, anomalous. These sentences were the same as those used in the earlier study. The subject was required to press a finger key as rapidly as possible upon presentation of a tape-recorded click through the second speaker, at 4, 6, 8, 10, or 12 seconds into the silent period following the presentation of each sentence.

Subjects were required to repeat each sentence verbatim twenty seconds after its presentation, to ensure that they attended to the sentence itself, as well as to the associated click. They had received 10 minutes of practice on both clicks in isolation and clicks following sentences, to ensure familiarity with the procedures.

Data Source

Twenty paid college students, serving in individual sessions, provided the data for this study.

Each sentence they heard contained five content words, and followed one of three structural patterns. In a fully grammatical sentence, all content words fit the context and the transitions between words were normal. The content words in an anomalous sentence were taken from grammatical sentences, but the transitions between them were made deliberately odd. Contrast, for example, "Loud parties wake sleeping neighbors," and "Union flies wake hardy typewriters." As can be seen from the example, the same structural patterns were used with anomalous sentences as with grammatical ones.

The two conditions of semantic relations, three of structural patterns, and five of click foreperiods yielded a balanced 2 x 3 x 5 within-subject design, given thirty sentences in the experiment. One random order of the thirty sentences was constructed, and that same order was presented to each subject.

Results and Conclusions

An analysis of variance for the reaction times (corrected for serial position of the sentence) yielded a significant effect for semantic relations ($F = 6.56$; $df = 1/541$). There was a linear downward trend for reaction times as a function of lengthening the click foreperiod ($F = 54.45$; $df = 1/541$), but this trend varied as a function of whether the sentence is grammatical or anomalous. Reaction times for anomalous sentences showed a strong linear downward trend, but those for grammatical sentences did not (F interaction = 12.04; $df = 1/541$). The reaction time means for anomalous sentences are much higher than those for grammatical sentences at 4 and 6 second foreperiods, but not for longer foreperiods.

The data support the hypothesis that the semantic organization of a sentence affects the ease with which it is processed, on the assumption that sentence-processing interferes with speed of responses to clicks. The effect of semantic organization seems to occur immediately after the full sentence is heard, rather than as it is heard. For grammatical sentences, semantic processing seems complete by four seconds after their presentation. Anomaly seems to delay the completion of this processing until perhaps eight seconds have passed, at least with sentences presented in isolation.

Scientific Importance of the Study

The Holmes and Forster method and the adaptation of it here seem useful for isolating the contemporaneous effects of grammatical variables upon sentence-processing performance. The data now available suggest that heard sentences are stored by individual words while parallel parsing for the sentence break goes on. The semantic processing of the sentence then takes place. Further studies may use this method to increase understanding of linguistic performance by specifying when other sorts of analyzers come into play, such as that for parsing into subject and predicate. Such studies may begin to test the validity of current grammatical models--not, of course, as hypotheses about how linguistic performance proceeds, but as hypotheses about the structures needed to describe such performance.