Verb Semantic Structures and On-Line Language Processing

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Abstract: *This paper describes the use of on-line processing of anaphoric reference to explore the structure of sentence representations. Of central concern is whether or not the representation of verbs is componential. The differential amounts of processing required by subjects to resolve references to objects and simple or complex actions was used to provide insights into the nature of the internal representation of sentences. Two conditions were created; one in which componential effects occurred, and another in which they did not. It was concluded that processing demands dictated the nature of the representation, and that either a wholistic or componential mode of representation could be used on-line with equal facility.*

Introduction

This paper will examine the issue of semantic decomposition in the context of the on-line processing of sentences. The concept of semantic decomposition has widespread appeal for linguists (Jackendoff, 1976), computer scientists (Wilks, 1977; Schank, 1975), and psychologists (Norman, Rumelhart, and the LNR Research Group, 1975; Gentner, 1981). Gentner (1981) points out that a decompositional approach allows one to account, within one framework, for subjective similarity in meaning, substitutability in paraphrases, and confusability in long-term memory.

However, in spite of its theoretical elegance, the psychological reality of semantic decomposition has not found much empirical support (Kintsch, 1974; Thorndyke, 1975). Gentner (1981) claims that this is due to inadequacies in the type of hypotheses that have been formulated, rather than in the theory itself. The typical hypothesis assumes that a decompositionally complex concept requires more processing to construct and its elements are more difficult to retrieve. Gentner distinguishes between two types of decompositional complexity, connective and non-connective. In a connectively complex representation there is a greater number of semantic relations between the elements representing the nouns in the phrase or sentence. In a non-connectively complex representation there are fewer redundant connections between these elements. Previous attempts to discover a complexity effect had confounded these two types of representation. To test the distinction, Gentner predicted that cued recall of nouns from a connectively complex representation should be better than from either a non-connectively complex or a simple representation. These predictions were borne out by the results of her experiments.

In light of Gentner's re-definition of decompositional complexity, the purpose of this study was to find evidence for semantic decomposition during the on-line processing of sentences. In keeping with the findings of Tyler and Marslen-Wilson (1977) and Marslen-Wilson and Tyler (1980), it is assumed that all useful sources of information are utilised on-line during the processing of a sentence or phrase. Neither syntactic nor semantic processing are considered autonomous. Both processes interact freely as they continuously update the meaning representation of the linguistic input.

Anaphora

The processing of anaphoric references was used as a tool to explore the structure of the internal representation of sentences. Linguistically, the anaphora used can be defined as 'surface', rather than 'deep' (Hankamer & Sag, 1976; Sag, 1979). The specific pro-form employed was the word "it". This can be made refer to a particular object, as in the sentence-pair "John read Mary's essay. It annoyed him." Then, simply by changing the final pronoun, thus: "John read Mary's essay. It annoyed her", the referent of the "it" is no longer Mary's essay, but the action of John reading Mary's essay.

The point of resolution of the "it" anaphoric reference in this type of sentence-pair is the occurrence of the final pronoun. Therefore, a measure of the length of time it takes to process the final pronoun should provide a measure of the ease with which the "it" reference is resolved. This in turn should depend on the nature of the representation being accessed in the resolution. If the representation is wholistic and non-verb-central, such as ACT (Anderson, 1976), then there should be no difference in the ease with which object and action references are resolved. If the representation is decompositional, such as MARGIE (Schank, 1975) or the LNR model (Norman, Rumelhart, *et al.*, 1975), it should take longer to resolve an action reference than an object reference. This is because of the diffuse way in which verbs are represented in such a system. Furthermore, if the action referred to is a connectively complex one, it should take longer still to resolve a reference to it. Also, if Gentner is correct, references to objects in a

connectively complex representation should be resolved more rapidly than if the representation were simple.

A third possibility is that the representation of verbs is wholistic, but that they are represented differently from nouns (Kintsch, 1974; Huttenlocher & Lui, 1979). In this case there should be a difference in the ease with which object and action references are resolved, but there should be no effect due to verb complexity. The following experiment was designed to test the above hypotheses.

Method

Subjects: Thirty-one students of St Patrick's College of Education served as voluntary subjects for this experiment.

Materials and Design: Eight pairs of core sentences were constructed. They were similar in form to the sample sentence-pair given earlier. The names, actions, objects, and outcomes were varied. However, all sentence-pairs were constructed so that either the pronoun "him" or "her" would be meaningful as the last word of the sentence-pair. From this core of eight, six groups of eight sentence-pairs were generated. They consisted of the following:

(1) Eight sentence-pairs in which the verb in the first sentence was conceptually simple, and in which the "it" in the second sentence referred to the object of the verb. The choice of verb was determined by the scheme proposed in Gentner (1981). Where possible, suitable simple/connectively complex verb-pairs which she used were also employed in this study.

(2) Same as (1), except that the verb was replaced with its connectively complex counterpart.

(3) Same as (1), except that the reference was to the action in the first sentence, rather than the object.

(4) Same as (2) except that the reference was to the action in the first sentence.

(5) Eight sentence-pairs containing a simple main verb, for which the subject was asked to provide either "him" or "her" as the appropriate continuation.

(6) Same as (5) except that the main verb was connectively complex.

In each of the above descriptions "same" means that the sentences were of the same syntactic form and that they contained the same verb. The names and gender of the individuals were varied, as were the objects of the verb. However, the objects were kept as similar as possible. For instance, "essay" in the sample sentence was replaced by "poem" or "article".

Procedure

Each subject was required to read all of the 48 sentence-pairs from a computer controlled display. The sentence were presented in two parts. The first part consisted of all of the pair except the final pronoun. In the case of the sample sentence-pair, the subject first saw "John read Mary's essay. It annoyed". After reading this, the subject pressed a key. This cleared the screen, started the timer, and displayed one of these three forms of word combination:

(1)	(2)	(3)
him	hut	her
had	her	him

A schematic representation of the presentation paradigm is given in Figure 1. In the case of word-pair (1) and (2), only one word of each pair could meaningfully complete the sentence. Depending on the gender of the actor in the first sentence the pronoun could cause the "it" in the second sentence to refer either to the object or to the action in the first sentence. In (1) and (2) the alternative word always began with "h" and was never a meaningful continuation of the final sentence.

The purpose of condition (3) was to discover what was the preferred referent in each of the eight simple and eight complex sentence-pairs. It was assumed that by the time the subjects encountered the final pronoun they were already predisposed to a particular referent. Word-pair (3) was designed to provide an approximate measure of this predisposition. This would permit the separation of the subjects' responses into two categories. One containing those responses where the subject had correctly anticipated the referent of "it", and one containing those responses where the referent had been falsely anticipated. Of course, this categorization could only be approximate, since it assumed that subjects' responses to (3) were consistent with their previous anticipations. The usefulness of this categorization will become more obvious in the discussion.

Having decided on the appropriate continuation the subject responded by pressing a key corresponding to either the top or bottom word position. This stopped the timer and caused the next sentence-pair to be

displayed. The process continued untill all 48 sentence-pairs had been read. The set of response times (in centiseconds) thus produced were assumed to measure the amount of processing required to resolve the anaphoric references. This was expected to be a fairly accurate measure of the amount of processing required to access the internal representation.

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T1  L1
      2  John analysed Mary's essay.  It annoyed
      3

T2  L1                                          her
      2
      3                                         hut
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(T = Time; L = Line.)

Fig. 1. A schematic representation of the presentation technique used in the experiment. Only the text of the sentence was visible to the subject.

Analysis and Results

Each subject contributed 2 x 2 x 8 response times of interest. These corresponded to the two levels of verb complexity (Complexity) by the two levels reference target (Referent) by the eight sentences. These data were divided into two sets. One set containing those observations where the subject might have correctly anticipated the referent, and one containing those observations where the subject might have falsely anticipated the referent. Membership of these categories was determined by the responses given for sentence types (5) and (6). Each subject's data matrix was then averaged over the sentence dimension. Observations outside the range MEAN ± 2.5 * SD, where the MEAN and SD were calculated over the 8 x 31 observations within each Complexity x Referent treatment cell, were excluded from the averaging. This yielded two sets of four observations per subject.

A 2 x 2 repeated measures analysis of variance was performed on each set of observations. Only the Referent factor proved significant in the analysis of the correct anticipation data; $F(1,30) = 17.81$, $p < .001$. However, both Referent and Complexity were significant in the analysis of the false anticipation data; $F(1,30) = 12.69$, $p = .001$ and $F(1,30) = 5.67$, $p = .024$, respectively. There were no significant interactions in either analyses. It was considered inappropriate to treat sentences as a random factor because of the way in which they were constructed. Therefore, no quasi-Fs were computed.

The cell means for each analysis are given in Table 1.

Anticipation	Verb Complexity	Referent	
		object	action
Correct	Simple	92.68	105.94
	Complex	92.85	108.34
Incorrect	Simple	100.00	110.47
	Complex	103.51	121.02

Table 1. Mean resolution latencies in centiseconds for the 31 subjects.

Discussion

The false anticipation data from the experiment are assumed to be a more sensitive measure of the processing involved in accessing the internal representation. This is because the subject must resolve the reference from scratch having anticipated the alternative one. The significant Referent effect in these data is an indication that verbs and objects are represented differently. However, almost the same difference between object and action references can also be found in the correct anticipation data (differences of 14 and 15 csecs. for correct and false anticipation, respectively). This means that the Referent effect is not a function of referent anticipation, even though anticipation did have a significant influence on response times, and in the obvious direction (correct anticipation: 101 csecs., false anticipation: 109 csecs.; $t = 3.12$, $df = 30$, $p = 0.004$). The possibility that readers always check for an object reference first, and then process other types of reference is ruled out by the fact that the Referent effect is equally strong under both anticipation conditions. If this heuristic was being used there would either be no Referent effect in the incorrect anticipation data, or a considerably diminished one.

The significant Complexity effect in the false anticipation data is evidence for the componential representation of verbs. However, the effect was not exactly as predicted from Gentner's formulation. It will be recalled that the connectively complex verbs used in this study should have, according to Gentner, increased the accessibility of the elements representing nouns. In other words, object references should have been more rapidly resolved when the representation was complex. The results do not bear this out. Resolutions of object *and* action references were impeded by the complexity of the representation, although it is obvious from Table 1 that the bulk of the Complexity effect is due to the difference between the two kinds of action reference. This

result throws some doubt on the notion of connective complexity.

The disappearance of the Complexity effect in the correct anticipation data and the robustness of the Referent effect in both sets of data would seem to indicate that the resolution of references in the experimental sentences occurs in two stages. In the first stage, prior to the display of the final pronoun, some form of anticipatory processing of the subsequent reference takes place. This processing primarily benefits action references. In the case of a potential reference to a complex action it probably involves the creation of a higher order node in the network to which a link can be subsequently established. Therefore, the representation of a verb can be either componential or wholistic, depending on processing demands. Resolution takes place only after the final pronoun has been encountered, and is differentially difficult. Action reference links are more difficult to establish than object reference links. Hence, the strong Referent effect in both sets of data. This may be due to the differing directionality of links between verb and noun elements in the representation.

In summary, the findings of this experiment support a componential system of representation. The results suggest that the reason why a verb complexity effect has been so elusive is that the task demands of a paradigm dictate the mode of representation used by subjects.

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