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SEGUI, Juan, et al.

Abstract

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THE PERCEPTUAL INTEGRATION OF SENTENCES: SYNTACTIC AND SEMANTIC ASPECTS

Juan Segui
Laboratoire de Psychologie Expérimentale
Université René Descartes et EPHE (3ème section), Associé au CNRS
Paris, France

Jean-Yves Dommergues, Uli Frauenfelder, Jacques Mehler
Laboratoire de Psychologie
Centre d’Etude des Processus Cognitifs et du Langage
Paris, France

Previous work using the RSVP procedure has shown that the reproduction probability of "nuclear" elements of a sentence was higher than that of "secondary" or "modifiers" elements. In order to reduce the importance of the preparation of verbal response on this task a new procedure which combines the RSVP method of presentation with a RT probe measure was used in three experiments. The results obtained in these experiments suggest that the observed differences between nuclear and secondary elements are not due to a preparation of verbal response but a selection process which takes place during the perceptual integration of a sentence. Semantic and syntactic parameters play independent roles in the perceptual integration process.

It is well established in psycholinguistics that the "nuclear" elements of a sentence are recalled better than the "secondary" elements such as modifiers (see Martin and Walter (1969), Wearing (1971), Segui (1974)). A similar phenomenon has also been observed in studies of sentence perception using the RSVP (rapid serial visual presentation) procedure. This technique involves presenting subjects the words of a sentence one at a time at high speeds (up to 16 or 22 words per second) in the foveal vision. The subject must reproduce as much of what he has read as possible.

Using this experimental procedure, Forster and Ryder (1971) and Holmes and Forster (1972) found that the reproduction probability for nuclear elements such as nouns and verbs was higher than that for modifiers like adjectives and adverbs. We would like to know whether there is a common underlying mechanism that accounts for the observed differences in perception and in retention of nuclear and secondary elements of a sentence.

To address this question, a first series of experiments were conducted in French using the RSVP paradigm (Mehler, Segui, Pittet and Barrière (1978)). It was shown that adjectives were not reproduced as frequently as the nouns they modified independently of their position with respect to the noun (preposed or postposed). This result was obtained not only for adjectives such as "jolie" (pretty) in (1), but also for adjective constituents of compound nouns like "sage" in (2) ("sage-femme" or literally "wise woman").

1. Le médecin a mis la jolie femme à la porte.
   (The doctor threw the pretty woman out.)

2. Le médecin a mis la sage-femme à la porte.
   (The doctor threw the midwife out.)
The subjects' failure to reproduce the adjectives under the extreme time pressures of RSVP was taken to be the consequence of a process in which the words of a sentence were selected on the basis of their "potential role". The potential role of any word was determined by its syntactic category and its syntactic context. Thus, for example, when in French an adjective is adjacent to a noun, the subject will tend to assign to it the "potential role" of a "modifier" (even for (2)) since that is generally the actual role of noun adjacent adjectives.

It should be noticed that the adjectives in sentences used were not semantically constrained by the sequential context. Thus, the omission of the adjectives in the preceding examples does not result in an anomalous sentence. It is reasonable to ask whether the reproduction of the adjective depends on the semantic context of the sentence. We attempted to study the reproduction of adjectives in constraining semantic contexts ((3) and (4)) (Dommegues, Frauenfelder, Segui and Mehler (1979)).

(3) Au coucher du soleil, les chauves-souris survolent le grenier.
    (At sunset the bats flow over the attic.)

(4) Au coucher du soleil, les chauves-souris envahissent le grenier.
    (At sunset the bats invade the attic.)

The results obtained for the sentences such as (4) are consistent with the previous findings. However, for the semantically constrained sentences such as (3), no difference in the reproduction of the noun and the adjective of the compound noun was observed. The high reproduction of the adjective in sentences like (3) can be explained in terms of a response bias. According to this explanation, the reproduction probability of semantically constrained adjectives should be independent of the amount of information they provide in the signal.

To test for this possibility, we compared the reproduction probability of semantically constrained adjectives in three different presentation conditions.

a.) in their correct form
b.) in the form of an anagram
c.) not presented at all (the adjective was absent).

This study showed that the reproduction probability was a function of the amount of information contained in the signal. In the third condition, the probability of restoring the missing adjective was close to zero; the reproduction probability was higher in the second condition and even higher in the first condition. Clearly, a response bias can not explain the difference in the subject's performance. These results indicate that the adjective was actually "processed" during the sentence presentation and not simply guessed.

Although, we could reject the response bias explanation for the semantically constrained adjectives, it is difficult to determine exactly what processes are being measured with the classical RSVP procedure in this case or in the case of the semantically unconstrained adjectives. In particular, we don't know whether the effects observed depend on processes of perceptual integration of the sentence or whether they are attributable to post-perceptual processes of reconstruction of or preparation for the verbal response.

Arguments for a post-perceptual interpretation of results obtained with the RSVP task have recently been given by Mitchell (1979). Mitchell argues that the time constraints operating in RSVP make it unlikely that the subjects could process the structural properties of the sentence in real time; the effects are claimed to be basically post-perceptual. In other words, the syntactic variables are
Three different rates of presentation were used: T1 = 150 msec./word, T2 = 175 msec./word, T3 = 250 msec./word. Three independent groups of subjects were associated with the three presentation rates. Each group was subdivided and assigned to either List 1 or List 2.

SUBJECTS

Forty-two adult subjects, all psychology students at the University of Paris V, participated in the experiment. Three groups (with 14 subjects each) were associated with each of the three presentation rates.

RESULTS

Table 1 shows the RTs and the percentage of errors for the noun and adjective probe at the different presentation rates.

<table>
<thead>
<tr>
<th>Probes</th>
<th>Adjective</th>
<th>Noun</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>779 (8%)</td>
<td>715 (4.4%)</td>
</tr>
<tr>
<td>T2</td>
<td>652 (4.2%)</td>
<td>614 (6.8%)</td>
</tr>
<tr>
<td>T3</td>
<td>706 (1%)</td>
<td>696 (2%)</td>
</tr>
</tbody>
</table>

As Table 1 shows, the largest RT difference between the noun and the adjective probes was obtained with the fastest presentation rates (10 msec. for T3, 38 msec. for T2 and 64 msec. for T1). An analysis of variance (VAR3, Lépine, Rouanet and Lebeaux (1975)) indicates that the syntactic category of the probe word introduced a significant effect (F (1,39) = 12, p < .01). The rate of presentation on the other hand does not have a significant effect (F <1). The interaction between the two factors is not significant. Nevertheless, specific comparisons show that the difference between the noun and the adjective is significant for T1 and T2 (F (1,13) = 8.93, p < .02 for T1 and F (1,13) = 5.04, p < .05) for T2, and not significant for T3 (F <1).

Whereas, the "positions" factor (preposed vs. postposed) does not introduce significant effects, the RTs to words at the beginning of sentences are significantly longer than to those at the end of the sentence (F (1,13) = 19, p < .01). This result is independent of the syntactic category of the word and probably reflects the easier access to items presented last (recency effect).

DISCUSSION

Significant differences in the RTs to nouns and adjectives were obtained for the fastest presentation rates. This result is consistent with the hypothesis that the selection of words according to their grammatical category takes place during the perceptual integration of the sentence. Such a process of selection would be increasingly necessary as the time available for this integration is decreased.
relevant after and not during the visual presentation of the sentence.

Although we don't agree totally with Mitchell's conception of "sentence perception" which he limits to those processes which take place "during" the stimulus presentation (in particular, the processes of identification of the words in a sequence), the issue he raises is very much to the point. In an earlier study, we also insisted on the great complexity of the processes intervening between the end of the sentence presentation and the beginning of the subject's response (Dommergues et al.). The time interval separating these two events provides one indication of the complexity of these processes. In the study by Mitchell, this interval is about 2 to 3 seconds.

In order to reduce the effects of the processes of reconstruction of the sentence, we used a new experimental procedure which combines the RSVP method of presentation with a RT probe measure. After having seen a sentence in RSVP, the subject must decide whether a probe word was in the sentence or not.

The aim of the first experiment is to replicate, with the new procedure, the differences in accessibility observed between the nouns and adjectives (as reflected by RTs).

EXPERIMENT I²

MATERIALS

Thirty-two simple active declarative sentences containing an adjective were constructed. The adjective was either preposed or postposed with respect to the noun it modified (either N1 or N2). Thus, there were 8 different tokens of each of the 4 different sentence types. In all the experimental sentences, the noun and the adjacent adjective have the same syllabic length and frequency in French.

1. Art + Adj + N1 + V + Art + N2
2. Art + N1 + Adj + V + Art + N2
3. Art + N1 + V + Art + Adj + N2
4. Art + N1 + V + Art + N2 + Adj

Two experimental lists were constructed with the same sentences but with different probe words. Thus, for a given sentence, subjects assigned to List 1 received a noun and those assigned to List 2 received an adjective. Subjects saw 4 noun and 4 adjective probes for each of the 4 basic syntactic structures. In addition to the test sentences there were 22 filler sentences and 8 warm-ups. For the filler sentences, the probes were 5 verbs, 5 nouns and 12 other words not in the sentence.

EXPERIMENTAL PROCEDURE

The words in the sentence were presented one at a time on a Hewlett-Packard screen which was controlled by a computer. A 200 msec. interval separated the offset of the last word of the sentence from the onset of the probe word. The probe word appeared in the middle of the screen. The first word of the next sentence appeared 1 sec. after the subject's response.

The subject's task was to decide whether the probe word was or wasn't in the sentence and to push the "yes" or "no" RT button as fast as possible. The "yes" response key was associated with the subject's dominant hand. The nature and the latency of the response was recorded automatically by the computer.
According to the original interpretation of the results (Mehler et al.,) the subjects select among the words in the sentences on the basis of their "potential role" in the sentence. This "potential role" of any word in a sentence is determined on the basis of two major factors: the syntactic category of the word and its syntactic environment.

To evaluate the relative importance of these two factors, the probe latencies for nouns and adjectives in normal and scrambled sentences can be compared. If the syntactic context guides the selection process, then the difference between RTs to noun and adjective probes for normal sentences should be decreased or eliminated for scrambled sentences. If the assignment of a potential role to a lexical item is done only on the basis of its grammatical category, then the same differences in probe latencies should be found for both types of sentences.

EXPERIMENT II

The aim of this experiment is to examine the RTs to probe words as a function of both their grammatical category and their syntactic environment.

MATERIALS

Thirty-two normal sentences with the same structure as those in Experiment I were constructed. An additional 32 scrambled sentences were obtained by randomly rearranging the 32 normal sentences. Thus, each normal sentence had a scrambled counterpart.

The 16 adjective and 16 noun probe words occupied the same serial position in the normal and the scrambled sentences. Thus, for example, the adjective "tenace" is the probe in sentences 5 and 6.

(5) Le coureur tenace renouvelle son exploit.

(6) Son renouvelle tenace le coureur exploit.

The word "STOP" was displayed at the end of each sentence to signal the end of the sentence and the onset of the probe. This marker was especially necessary for the scrambled sentences.

In order to counterbalance the linguistic materials, 2 experimental lists (I.1 and I.2) were constructed. Each list was made up of 16 grammatical test sentences, 16 scrambled test sentences, 16 grammatical distractor sentences and 16 scrambled distractor sentences. Each subject received only one version (grammatical or scrambled) of any given sentence.

EXPERIMENTAL PROCEDURE

The procedure is identical to that used in Experiment I.

SUBJECTS

Twenty adult subjects, all psychology students at the University of Paris V, participated in the experiment. Two groups (with 10 subjects each) were associated with L1 and L2.

RESULTS

Table 2 shows the RTs (in msec.) and the error percentage for the two types of
probes (noun and adjective) as a function of the type of sentence (normal vs. scrambled).

Table 2

<table>
<thead>
<tr>
<th>Probes</th>
<th>Adjective</th>
<th>Noun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal sentence</td>
<td>869 (11.8%)</td>
<td>798 (7.5%)</td>
</tr>
<tr>
<td>Scrambled sentence</td>
<td>911 (13.7%)</td>
<td>896 (13%)</td>
</tr>
</tbody>
</table>

Table 2 shows that the difference between RTs to noun and adjective probes is much greater for the grammatical sentences than for the scrambled sequences (71 msec. vs. 15 msec.).

An analysis of variance reveals that the interaction between the two main factors (grammatical category of the probe and the type of sentence) is not statistically significant \(F(1,19) = 1.17\). The specific comparisons, on the other hand, showed a significant difference between the noun and the adjective for grammatical sentences \(F(1,19) = 6, p < .02\) and no difference for the scrambled "sentences" \(F < 1\).

Globally then the factor type of "sentence" gave a significant effect \(F(1,19) = 11.6, p < .01\) and probe type gave only a slightly significant effect \(F(1,19) = 3.3, p < .10\).

DISCUSSION

The difference in accessibility between the nouns and adjectives in normal sentences confirms the results obtained in Experiment I. The absence of a difference for the scrambled "sentences" supports our hypothesis that the selection (and retention) of words depends on the surrounding syntactic context. Syntactic factors seem to play an important role in the selection of the words in the sentence. It appears that the words in a sequence are more accessible to the subjects when they can impose a structural organization on the sentence.

It would be important to discover whether these structural effects are independent of the meaning of the sentence or not. In the following experiment, we compared the RTs to probe words as a function of the syntactic organization and of the semantic characteristics of the sequence.

EXPERIMENT III

EXPERIMENTAL MATERIALS AND PROCEDURE

The linguistic materials for this experiment were 2 sets of 32 sentences: normal (N) and anomalous (A). The A type sentences contained a violation of a selectional restriction:

(7) La fille liquide écoute la fleur.
    (The liquid girl listens to the flower).
The syntactic structure of the sentences in sets N and A were the same as those used in the two previous experiments. Using these two sets of sentences, we constructed 2 different experimental lists: the normal list (NL) and the anomalous list (AL). The former had 16 N sentences in order and 16 N sentences scrambled, and LA had 16 A sentences in order, and 16 scrambled A sentences. This was done so that each of the original 64 sentences was presented scrambled and unscrambled.

The syntactic organization (scrambled or unscrambled) was a within subjects variable, while the meaning was an across subjects variable, while the meaning was an across subjects variable. In addition to the 32 experimental sentences in each list (normal in LN and anomalous in NA), there were 15 warm-up and 20 distractor sentences.

As in the first two experiments, the probe word occupied the same serial position in the scrambled and unscrambled sentences. In this experiment, the probe word could be any element of the sentence; (6 N1, 6 N2, 6 Adj 1, 6 Adj 2, 8 V). This was done in order to increase the subject's uncertainty concerning the probe word. As in the preceding experiment, the word "STOP" was presented as the last item of the sentence.

The experimental procedure was identical to that used in the Experiment II.

SUBJECTS

Two independent groups of twenty adult subjects, all psychology students at the University of Paris V, participated in the experiment. These two groups were associated with NL and AL.

RESULTS

Table 3 shows the RTs (in msec.) and the error percentage for the different experimental sequences.

<table>
<thead>
<tr>
<th>Sentences</th>
<th>Normal</th>
<th>Anomalous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unscrambled</td>
<td>832 (9,7 %)</td>
<td>863 (17,5 %)</td>
</tr>
<tr>
<td>Scrambled</td>
<td>886 (13,4 %)</td>
<td>903 (20 %)</td>
</tr>
</tbody>
</table>

As can be seen in Table 3, there are more errors for the anomalous sentences than for the correct ones. The difference is of the same order of magnitude for the unscrambled and scrambled sentences (7,8 % and 6,6 %). An analysis of variance conducted on the errors showed that there was a significant effect of the semantic variable (F (1,18) = 6.38, p < .02). The effect of the variable, syntactic organization is much smaller (F (1,18) = 3.6, p < .10). The interaction of these two variables is not significant (F <1).

An analysis of variance of the RTs shows that only the factor "syntactic organization" introduced a significant effect (F (1,38) = 16.8, p < .001). The difference in RTs between the unscrambled and scrambled order is of approximately the same
order of magnitude for the normal and the anomalous sentences (53 msec. and 40 msec., respectively).

DISCUSSION

The results obtained in Experiment III show that both main factors (the syntactic organization of the sequence and its meaning) introduced large, but different effects. Whereas the role of the semantic factor is primarily reflected in the error rate, the effect of the syntactic factor is found in the RTs.

These results are compatible with those obtained by Forster and Ryder (1971) who used the classical RSVP procedure. In their study as well as in ours, the effect of the syntactic organization is independent of the semantic characteristics of the sentence (i.e. correct, bizarre, and anomalous).

The high error rate observed for the anomalous sentences (about 20 %) suggests that the subjects, unable to reach a coherent semantic interpretation, had difficulties integrating these sentences types.

The syntactic organization of the sentence also has important consequences on the subject's performance. Subjects can easily construct a well integrated representation of a sentence presented in the correct order, but not in a scrambled order.

GENERAL DISCUSSION

The central objective of Experiment I was to determine whether the difference in reproduction of nouns and adjectives observed with classical RSVP reflected perceptual processes or post-perceptual processes involved in the preparation of the verbal response. The results obtained with a new procedure (combining RSVP presentation with a RT measure) allowed us to reject the latter processes in favor of the former. Indeed, we found that there were significant differences in access time to words of different syntactic categories and that these differences increase with increasing rates of presentation.

This result suggests that the effects observed depend on the processes of perceptual integration that allow the subject to assign a meaningful structure to the stimulus sequence. We proposed the hypothesis that these integrative processes involve a selection among the words in the sequence on the basis of their "potential" role. Recall that the "potential" role attributed to a word is determined by both the syntactic category of the word and the syntactic context in which the word is found.

The main result of the Experiment II is consistent with this interpretation. It was shown that when the words are presented in random order, nouns and adjectives are equally accessible. This result demonstrates the importance of the syntactic context in the process of selection of the words of a sentence.

Finally, Experiment III demonstrated the role of semantic factors as reflected by the difference in number of errors for normal and anomalous sequences. The high rate of errors observed in the latter sequences shows the difficulty subjects have in integrating them.

This experiment, however, also showed that the effects due to the syntactic organization of the sentences are independent of these semantic effects. Indeed, the effect of the syntactic organization of the sentence was the same independently of the semantics of the sentence (normal or anomalous). Such a result suggests that the subject's analysis of the syntactic properties of the sentence is not affected by the anomalous character of the sequence. Clearly, this hypothesis does
not imply that semantics do not play a role in this integration process (our
results show that they do); it simply indicates that the syntactic analysis of the
stimulus sentence can not be altered by its anomalous aspect. Semantic and syn-
tactic parameters play independent roles in the perceptual integration process.

These results are consistent with the autonomy hypothesis proposed by Garrett and
Forster among others. In its strongest form, this hypothesis suggests that the
syntactic processing of a sequence lexical items is independent of their meaning.
No claim is made about the temporal ordering of the syntactic and semantic
processing, just about their independence. Evidence for the independence of these
two types of processing supports a view of language processing in which separate
sub-systems are operating. Despite the difficulty in validating the independence
of separate processing components, this view provides a precise and well structu-
red theoretical framework.

FOOTNOTES

Reprint requests should be sent to Dr. Juan Segui, Laboratoire de Psychologie
Expérimentale, 28 rue Serpente, 75006 - Paris, France.

1 The authors wish to express their thanks to Madeleine Léveillé for her help
in preparing and running the experiments.

2 This experiment was conducted with the help of Sylvie Ledoux.

3 The presentation rate of 150 msec./word was selected on the basis of the results
of a pilot study in which subjects correctly responded to 90% of the probe
words in semantically and syntactically acceptable sentences. A relatively
high percentage of correct responses is needed if one wants to use RTs to
probes as the principle behavioral index. This presentation rate of 6.6 words
per second is considerably slower than those rates used in traditional RSVP
experiments (16-22 wps). However, it is unreasonable to directly compare
these rates because there are large differences in the quality of the visual
display (i.e. 16 mm films vs. computer screen displays).

4 The relative importance of the syntactic and semantic factors on the subjects’
performance must be interpreted with caution since two independent groups did
not receive the same linguistic materials in the case of the semantic variable.

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