

SENTENCE MEMORY IN APHASIA

ALFONSO CARAMAZZA*

Department of Psychology, The Johns Hopkins University, Baltimore, Maryland 21218, U.S.A.

and

EDGAR B. ZURIF and HOWARD GARDNER

Aphasia Research Center, Boston University School of Medicine,
and Veterans Administration Hospital, Boston, Massachusetts, U.S.A.

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Abstract—A probe paradigm was used to assess memory for the surface structure of sentences in a group of anterior (Broca's) and a group of posterior (Wernicke's) aphasics. Three types of sentences were used: active, passive and center-embedded sentences. Results showed that for both patient groups memory for function words was especially impaired relative to the patient's ability to recover content words. Further, both groups had marked difficulties in remembering center-embedded sentences. A second experiment rules out the possibility that this latter result was due to the extra syntactic complexity of the center-embedded sentences. Results from both experiments were interpreted as indicating that neither anterior nor posterior aphasics have normal surface structure memory representations and that the aphasic's memory span for sentence material may be severely limited.

RECENT work on the topic of sentence comprehension has emphasized the constructive nature of the process involved. That is, comprehension of a sentence requires the construction of an internal representation that encodes the meaning of individual lexical items as well as the syntactic and semantic relations among those items. This constructive process underlying sentence comprehension is believed to provide the basis for the representation of sentences in memory [1].

The representation that is initially constructed may undergo further abstraction and integration into more complex ideas consistent with contextual information and personal knowledge [2]. Even so, there is a brief period of time following the presentation of a sentence in which the subject has available a fairly veridical representation of that sentence—a representation from which detailed information about specific lexical items and about the exact syntactic form of the sentence can be retrieved [3, 4]. However, whether or not this initial representation and subsequent constructions will be available depends upon the "depth of processing" the sentence receives at the time of input [5].

With these interrelated notions concerning initial sentence processing as a starting point, the present paper attempts to characterize the form of memory representations that are generated by anterior (Broca's) and posterior (Wernicke's) aphasics. In addition, it attempts to describe the type of syntactic and semantic processing performed by these patients in encoding sentences.

*Please address reprint requests to Alfonso Caramazza, Department of Psychology, The Johns Hopkins University, Baltimore, Maryland 21218, U.S.A.

In the past several years, a number of investigators have addressed the problem of memory limitations in aphasia. Despite many unresolved questions, there appears to be general agreement on one point: namely, that the memory limitations in aphasia typically involve difficulties in retrieval from short term memory (STM), but not from long term memory (LTM) [6, 7]. This appears to be the case for aphasics as a group [8], but particularly for conduction aphasics [9, 10] and Broca's aphasics [11, 12]. Thus, when a memory deficit appears to be implicated in aphasia, it has been characterized as a deficit in a memory structure (or process) that represents information in a relatively veridical format.

The memory limitations observed in aphasic patients could result from a language specific encoding deficit—linguistic information is not processed adequately and is, therefore, poorly remembered. In such a case, memory performance in different types of aphasics should be a function of their respective processing limitations. Within this context, earlier research has suggested some specific processing limitations associated with brain damage to the anterior and to the posterior language areas of the dominant hemisphere [13–15]. Thus, assuming that Broca's and Wernicke's aphasics have different types of processing problems, it is likely that the availability of parts of the memory representations formed may differ.

The experimental paradigm used to explore this issue was a modified memory probe technique [17, 18]. Patients were presented orally with a sentence and immediately afterwards were given a word from that sentence. The patient's task was to correctly recall or identify the word that followed the probe item in the sentence. This task is especially sensitive to the structure of the internal representation constructed for the sentence, since a correct response requires that the subject retain a faithful representation of its surface form.

Based on the foregoing, a hypothesis can be formulated about the relative ability of the two patient groups to retrieve surface structure information of sentences. The hypothesis rests on the notion that anterior aphasics cannot adequately process function words, i.e. that class of free morphemes (e.g. *the* and *to*) and bound morphemes (e.g. *-ed* and *'s*) which function primarily as carriers of syntactic information [13, 15]. Since memory for lexical items is a function of the degree of processing or elaboration they receive at the time of encoding, it was hypothesized that the anteriors' memory for functors will be poorer than memory for content words (e.g. nouns and verbs), the latter receiving more elaborate processing. That is, the relatively shallow processing of functors was expected to result in less stable memory traces for these items.

Anticipating performance for the posterior aphasics is more difficult. In contrast to anterior aphasics, they appear to have retained the ability to process syntactic information. On the other hand, they are more impaired in the ability to process lexical-semantic information [13, 15]. Therefore, they ought to show the opposite effect of that predicted for anterior aphasics. Specifically, they should remember functors better than content words. However, this prediction, though not entirely counterintuitive, implies the unlikely ability to form syntactic representations in the absence of adequate processing and representation of major lexical items. It is more likely that since posterior aphasics process content words only imperfectly that they may not recover enough syntactic information from these items (e.g. categorical and strict subcategorization information) to construct well-formed surface structures. In this case, then, the posterior like the anterior aphasic, may have to rely on whatever semantic information he is able to capture from the sentence and his memory for the surface form should be equally poor.

METHODS

Subjects

Nine male aphasic adults were tested in the first experiment. These patients were classified as to lesion site and type of aphasia on the basis of clinical examination, laboratory data where available (CT scan and EEG), and the Boston Diagnostic Aphasia Examination [19]. Five of the patients had damage to the anterior portion of the left hemisphere and four patients had damage to the posterior portion of the left hemisphere, all as a result of stroke. The anterior patients presented the classical symptoms of Broca's aphasia—non fluent, agrammatic speech within the context of grossly normal comprehension. The posterior patients showed the "fluent" but empty speech and impaired comprehension characteristic of Wernicke's aphasia. Five neurologically intact male patients served as control subjects in the first experiment.

The subjects in the second experiment were six male Broca's aphasic patients, all with anterior left hemispheric damage. These patients were classified according to the same criteria applied to the patients selected for the first experiment.

Task and stimuli

Patients were tested individually, following the same procedure in both experiments. A stimulus sentence was presented orally with normal conversational intonation. Immediately following this presentation, the patient was presented orally with one word from the sentence and asked to recall the word that followed it. If the patient responded incorrectly by producing a word that was not in the stimulus sentence, or if he did not respond at all within 15 sec, the sentence was repeated and the patient was provided with a multiple-choice array from which to choose the correct word. This multiple choice alternative was not provided on any trial in which the patient's response was an incorrect word from within the stimulus sentence itself. A multiple choice alternative was not provided in the latter case since the subject having obtained feedback that the word he produced was wrong, would be unlikely to select that word from a subsequent multiple choice array, and a correct multiple-choice response in such instances would be difficult to interpret.

Multiple-choice alternatives consisted of the remaining words of the sentence. The alternatives were delivered orally immediately following the oral presentation of the probe word. That is, the probe word was repeated prior to each of the randomly presented alternatives. In addition, the examiner "counted-off" each probe-alternative pair by successively raising a finger. This enabled the patient to indicate his choice by pointing to one of the examiner's four extended fingers.

The patients were trained with 10 sample sentences to produce words orally and to select words from among multiple alternatives in response to probe items. Formal testing began only after the patients clearly demonstrated both that they understood the nature of the task and that they had mastered the response procedures.

The stimuli for the first experiment consisted of active affirmative declarative sentences (e.g. The dog chased a cat.), passive sentences (e.g. The books were delivered by John.), and object-relative center-embedded sentences (e.g. The bike that John holds is broken.). A total of 174 sentences was presented. This large number of stimulus sentences was necessary so that a reasonable performance sample at each word position could be obtained for each of the sentence types. For example, the center-embedded sentences were constructed to be seven words in length. In order to obtain six probes for each word position without using the same sentence more than once, six sentences were constructed for each of six positions—36 sentences altogether. In fact, six probes per position for the center-embedded sentences was the minimum sample obtained for any one sentence type. There were 48 five-word active sentences, permitting 12 probes per position, and 90 six-word passive sentences, permitting 18 probes per position. Obviously, since the probe item always preceded the item to be recalled, there would be no probe for the first word of a sentence.

A greater number of active and passive sentences were included to test the effect on sentence memory of two non-syntactic variables. The first of these concerns the distinction between semantically-constrained and semantically-reversible sentences. For example, the sentence, "The man met a lady", is reversible in the sense that it is plausible for either person to meet the other. In contrast, "The cat ate a cookie" is semantically constrained in that while cats can eat cookies, cookies cannot eat cats. The second non-syntactic variable involves the lexical distinction between pronouns marked for possession (e.g. My cat ate his cookie) and articles (e.g. The cat ate a cookie). Neither of these semantic manipulations, however, had any effect on performance in the present task. Therefore, although we retained all the sentences for purposes of analysis and thereby included different numbers of exemplars of each sentence type, we disregarded the two aforementioned sentential and lexical semantic distinction.

In summary, the sentences delivered to the patients in the first experiment fell into one of the following three categories: (1) simple active sentences (48 sentences—12 probes per position); (2) passive sentences (90 sentences—18 probes per position); and (3) center-embedded sentences (36 sentences—6 probes per position).

The second experiment described in this study was undertaken to determine the effects of three factors upon sentence memory—the number of words in a sentence, the number of propositions in a sentence, and

the syntactic arrangement of these propositions. Three types of sentences were used for this purpose: 24 seven-word single proposition sentences containing a direct and indirect object (e.g. Bob hit a ball to the boy); 24 seven-word sentences containing two propositions in a right-branching arrangement (e.g. John holds the bike that is broken); and 24 seven-word sentences containing two propositions, one embedded in the other (e.g. The bike that John holds is broken). The number of sentences permitted four probes per position of each of the three constructions.

RESULTS AND DISCUSSION

Results were analyzed in terms of transitional error probabilities (TEP)—the probability of recalling an item other than the one that actually followed the probe in the sentence. Separate analyses were carried out first, for data generated solely by the patients' productions and second, on the production data combined with multiple choice responses. Identical patterns of results obtained for the two types of data and only the production plus multiple choice data are reported, since these responses should give a more accurate index of the patient's internal representations. That is, the multiple choice score does not penalize the patient for poorly articulated responses and other impediments that are not of concern here.

The mean TEPs within sentence types for each patient group are presented in Table 1. The control group did not produce an appreciable level of errors. Therefore, analyses were carried out only for the data from the aphasic group; assessment of possible differences in the pattern of performance between the aphasic patients and normal subjects will rely on published data [26].

Table 1. Transitional error probabilities

								Mean TEPs
	The	cat	ate	a	cookie			
Anterior	0.58	0.40	0.80	0.38				0.54
Posterior	0.56	0.40	0.73	0.58				0.56
	The	books	were	delivered	by	Jane		
Anterior	0.33	0.83	0.40	0.69	0.44			0.54
Posterior	0.34	0.72	0.64	0.73	0.47			0.58
	The	bike	that	John	holds	is	broken	
Anterior	0.56	0.86	0.90	0.70	0.86	0.40		0.71
Posterior	0.25	0.100	0.96	0.79	0.87	0.37		0.70

An analysis of variance on mean TEPs for sentence type and the two aphasic patient groups revealed a significant main effect for sentence type [$F(2, 16) = 36.894, P < 0.001$]. Neither the main effect of patient group ($F < 1$) nor the interaction of patient group by sentence type ($F < 1$) was significant. Separate analyses of variance for each sentence type revealed significant main effects for probe item (transition position). Neither the main effects of patient group nor the interaction of patient group by probe item were statistically significant in any of the sentence types. The fact that there was no difference between patient groups indicates that anterior and posterior aphasics do not differ in overall memory capacity for sentence material, at least for the experimental task employed here. Moreover, since there was also no evidence of differential retrievability of parts of sentences as a function of patient group (i.e. no significant probe item by patient group interactions) it would seem that the patients' internal representations are elaborated to comparable levels and structurally similar at these levels. However, given the very well-established clinical fact of relatively poor comprehension for Wernicke's aphasics, and given also the fact that this task did not specifically require comprehension, it may be

possible that the levels under discussion do not include one at which the semantic facts of the sentence are fully recovered.

The results raise an important question about presumed differences between anterior and posterior aphasics in their ability to process syntactic information. On the basis of the data obtained here, the simplest hypothesis is that posterior aphasics make only minimal use of syntactic information in the comprehension process. This claim is not as implausible as it may at first appear—after all, syntactic information can only be obtained if one can process the lexical items that convey this information. It is at precisely this level—lexical processing—that posterior aphasics are impaired. A corollary of this claim is that comprehension performance in posterior aphasics should be relatively unaffected by syntactic complexity since syntax is not reliably retrieved in their lexical processing. In support of this view, it has been reported that posterior patients' performance is not related to the type of syntactic structure of the sentences used [16].

A more detailed analysis of the patients' performance on this task is available from the pattern of TEPs within sentence types. As can be seen from Table 1, and confirmed by the analyses of variance, different parts of the sentences are differentially retrievable. Thus, for both patient groups retrieving function words is more difficult than retrieving content words.

If mean TEPs are combined over active and passive sentences (for which overall performance was virtually identical), the mean TEP from content word to function word was 0.75 while that for function words to content words is only 0.47. This represents a 28% difference that is highly reliable statistically [$F(1, 7) = 24.37, P < 0.005$]. Statistically significant differences were also obtained for active and passive sentences analyzed separately. The interaction of patient group by transition type was not significant in any of the analyses carried out. These results clearly support the contention that the internal representation of function words is less stable than that for content words. The functors received sufficient processing for their traces to be reinstated when they served as probes, but not to a level sufficient for the words themselves to be retrieved.

It should be noted that this result is not merely a consequence of the content word to function word transitions being located at phrase boundaries, i.e. the fact that function words mark the beginning of a constituent and that they can be probed only by an element outside of that constituent. For example, in the sentence: "John hit the ball", "the" probes "ball", a within constituent function to content word transition, while "hit" is used to probe "the", a between constituent content word to function word transition. If anything, the data reported points to the absence of an effect due to phrase structure alone. Thus, in the case of active sentences both patient groups made substantially more errors for within phrase transitions ("the" to "cat") than for between phrase transitions ("cat" to "ate") for content words. In the case of phrase boundary transitions, the mean TEP for content word to content word ("cat" to "ate") was about half as much as that from content word to function word ("ate" to "a"). It would appear, then, that the critical factor is not constituent location but the type of lexical item involved in the transition.

A second aspect to note in these data is the fact that the pattern of TEPs differs markedly from that typically obtained for normal subjects [17, 18]. Thus, as noted above, the aphasic patients we tested produce relatively high error rates at phrase boundaries only when the boundaries are marked by function words. When the phrase boundary falls between two content words the error rate is relatively low. This pattern contrasts with that reported for normal subjects, who make more errors (or respond more slowly in reaction time experiments) for transitions at phrase boundaries quite independently of whether they are marked

by function or content words [17, 18]. It would appear, then, that the aphasic groups studied are relatively insensitive to surface structure properties of sentences.

The data from the center embedded sentences were not included in this analysis because this sentence type differs in important ways from the previous two, both from a linguistic viewpoint and in terms of the data obtained. As can be seen from Table 1, in the center-embedded sentences, as opposed to the other sentence types, the TEPs from function words to content words are especially high at certain points. The errors arise specifically at the clause boundary between the embedded and the matrix clauses of the center-embedded sentences. That is, it appears that these patients may have experienced difficulties in the transition from one clause to the other, reflecting a potential disturbance at the level of integration of clauses. Unfortunately, this interpretation of the data can only be tentative because of a confounding between sentence structure and serial position of words in the sentence. Thus, it could be argued that if the sentence was too hard for the patient to understand, he might treat it as a nonorganized string of words subject to the serial position effect in memory performance. In that case, memory would be better for the early and late parts of a list than for the middle part. Though possible, this interpretation of the data is not likely to be correct since a similar effect does not obtain in the passive sentences, where a function word to content word transition occurs in the middle part of the sentence.

A further aspect to be noted in the data is the overall level of performance for sentence type and patient groups. These data are at the extreme right end of the table. As can be observed from this column there is no difference in performance level between active and passive sentences, but there is a substantial difference between these two sentence types and center-embedded sentences. Center-embedded sentences differ however in several other ways from active and passive sentences, making it difficult to draw firm conclusions from the data. Thus, the basis for the obtained differences in performance level could be attributed to any of three factors. First, center-embedded sentences are longer than the active and passive sentences. Second, center-embedded sentences contain two clauses, while the active and passive sentences contain only single clauses; and third, center-embedded sentences involve special processing mechanisms related to the interruption routine for temporarily storing the subject noun phrase of the matrix clause while the embedded clause is processed.

The second experiment was designed to help choose among these alternative hypotheses. This experiment was identical to the first one in all respects except that this time stimulus sentences permitted a test of the listed hypotheses. Three different sentence types were used: center-embedded, right branching ("John bandaged the girl that was cut"), and sentences seven words long with only one clause ("Bob hit a ball to the boy"). The center-embedded and right branching sentences differ in that one (center-embedded) involves an interruption routine while the other (right branching) does not. The difference between these two sentence types permits a test of the hypothesis that aphasic patients are relatively incapable of processing sentences that require the interruption of a clause to process an embedded one. The center-embedded and right branching sentences differ from the third sentence type in that the first two contain two clauses while the third contains only one clause. This contrast allows a test of the hypothesis that aphasics are especially impaired in processing sentences with two clauses *v* single clause sentences.

The results obtained do not differ in any important respects from those reported for the first experiment. Again, the TEPs from content word to function word were significantly larger than for function word to content word transition (0.60 vs 0.49). Also, the pattern of

TEPs, in contrast to normals, again revealed an insensitivity to phrase boundaries. On the major variable of interest here, however, there were no significant differences in overall performance across sentence types. This result suggests that the differences between sentence types reported earlier may simply be due to sentence length and not to any linguistically specific aspects of the sentence types used. That is, seven words may exceed the memory span of the patient groups tested, resulting in a larger error rate for these sentences.

Conclusions

The data reported allow two conclusions: one concerns the issue of memory deficits associated with anterior and posterior aphasics; the other bears on the question of the memory representations that anterior and posterior aphasics form for sentence material. With regard to the first of these two questions, the results obtained in this investigation suggest a limitation of storage capacity for verbal material. What is not clear, however, is whether this limitation is language specific. The capacity limitation observed may result from a generalized language processing difficulty in the sense that language processing is so difficult for these patients that considerably more effort is involved in retaining verbal than non-verbal material in memory.

Stronger conclusions can be reached with respect to the second question—namely, the nature of the memory representations for sentences formed by the two patient groups. The pattern of results reported lend strong support to the view that, while at least posterior aphasics have some control over syntax in their verbal output, neither patient group could reliably use syntactic information in sentence processing or in the construction of memory representations. Specifically, the results support the hypothesis that memory for function words is impaired, reflecting the patients' inability to process syntactically relevant information. Function words and other grammatical morphemes play a crucial role in models of language processing—especially of comprehension [1]. It is these grammatical markers that form the basis for most of the proposed syntactic strategies involved in parsing and assigning a syntactic structure to sentences. Inability to make use of these grammatical elements leaves the patient with a very impoverished set of processing strategies—essentially only those that can be based on content words. It would appear, then, that to the extent that aphasic patients have retained an ability to process content words they can form imperfect or partial memory representations for sentences and can comprehend sentences where processing of grammatical morphemes is unnecessary. However, to the extent that sentence comprehension or sentence memory requires processing grammatical morphemes, aphasic patient's performance will be seriously affected.

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Résumé :

On a utilisé un paradigme de sondage pour étudier la mémoire des structures de surface dans un groupe d'aphasiques antérieurs (Broca) et dans un groupe d'aphasiques postérieurs (Wernicke). On a utilisé 3 types de phrases : actives, passives, et phrases enchassées. Les résultats montrent que pour les 2 groupes de malades, la mémoire des mots fonctionnels était spécialement troublée par rapport aux capacités de retrouver les mots pleins. En outre, les 2 groupes avaient de nettes difficultés pour se souvenir des phrases enchassées. Une 2ème expérience exclut la possibilité que ce dernier résultat soit dû à la complexité syntaxique des phrases enchassées. On considère que les résultats de ces 2 expériences indiquent que les représentations mnésiques des structures de surface ne sont normales ni chez les aphasiques antérieurs ni chez les aphasiques postérieurs et que l'empan mnésique des aphasiques pour les phrases peut être gravement réduit.

Deutschsprachige Zusammenfassung:

Bei einer Gruppe von Broca-Aphasikern und einer Gruppe von Wernicke-Aphasikern sollte mit Hilfe eines (Sprach-) Beispiels die Merkfähigkeit für Oberflächenstrukturen von Sätzen festgestellt werden. Drei Typen von Sätzen wurden verwandt: Aktivsätze, Passivsätze und zentral eingebettete Sätze. Die Ergebnisse zeigten, daß bei beiden Patientengruppen die Merkfähigkeit für Funktionswörter besonders gestört war im Vergleich zu ihrer Fähigkeit, Inhaltswörter wiederzufinden. Darüber hinaus hatten beide Gruppen ausgeprägte Schwierigkeiten, zentral eingebettete Sätze zu behalten. Durch ein zweites Experiment wird die Möglichkeit ausgeschlossen, daß das zuletzt genannte Ergebnis auf besondere syntaktische Komplexität der zentral eingebetteten Sätze zurückzuführen sei. Die Ergebnisse der beiden Experimente wurden so interpretiert, daß sie anzeigen, daß weder die prae-rolandischen noch die post-rolandischen Aphasiker sich Oberflächenstrukturen normal wieder vergegenwärtigen können und daß die Retentionsspanne der Aphasiker für Satzmaterial erheblich begrenzt sein kann.