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Tails of Words: Monitoring Ambiguity

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In order to measure reaction times for the detection of a phoneme target appropriately, the length and frequency of the word preceding the target phoneme should be controlled, but this control has been lacking in earlier studies. The addition of these controls, particularly for length, made possible the demonstration that the ambiguity of the word preceding a target phoneme did not cause an increase in the time required to detect the phoneme. This result tends to disconfirm the hypothesis that the presence of an ambiguous word necessarily complicates the real-time processing of a sentence. In fact, French sentences with a long ambiguous word just before a target phoneme led to faster reaction times than did sentences with a short unambiguous word just before the target phoneme.

The two principal hypotheses on the processing of ambiguous sentences are (1) the exhaustive computation hypothesis, according to which a subject computes all the possible readings of a sentence, and (2) the unitary perception hypothesis, according to which a subject normally seeks and finds only one reading for a sentence, except in special cases, when he may find two or more readings. The second hypothesis results from the view that syntactic, semantic, and pragmatic context normally constrains the construction of a reading for a sentence in such a way that a single reading is constructed, even when several grammatical constructions are possible (Carey, Mehler, & Bever, 1970). Occasionally, on the second hypothesis, a reading that is in the process of being constructed, or even a completed reading, may turn out to be incompatible with some portion of the context; at that point, the first reading may be superseded or augmented by a second reading. These exceptions to the unitary perception hypothesis are usually cases where the subject is aware of the exceptional nature of the second construction, whereas, according to the first hypothesis, subjects are usually aware of only one reading, in spite of the putative fact that at early levels of processing, they have constructed all the readings in parallel, selecting a single reading for full awareness.

In the experiment reported here, these hypotheses were tested with French sentences containing ambiguous lexical items, i.e., words with two distinct semantic readings, such as the word *avocat*, which can have the reading "avocado" or the reading "lawyer." Previous research on sentences containing lexical ambiguities has often yielded contradictory results, which have been highly dependent on the experimental procedures employed. In experiments by Lackner and Garrett (1972) and by MacKay (1973), subjects either shadowed or paraphrased aloud ambiguous sentences that were played back to one ear, while a different message, to be "ignored," reached the other ear. Results showed that the message to be ignored, when it contained

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phrases that were semantically related to one of the interpretations of the concurrent ambiguous sentence, effectively biased the subjects' interpretation of the ambiguous sentence in the direction of the phrase. These results, while extremely interesting, do not necessarily disconfirm either the exhaustive computation hypothesis or the unitary perception hypothesis, since the biasing effect can be interpreted in either of the following manners: (a) The effect of the disambiguating phrase is to cause a subject to select that member of the set of already computed readings that is most closely related to the phrase in the "unattended" ear; this interpretation of the phenomenon tends to leave the exhaustive computation hypothesis unscathed; or (b) the phrase in the "unattended" ear functions in the manner of ordinary context to bias the construction of a single reading during those instants when it is being constructed; this interpretation of the phenomenon tends to leave the unitary perception hypothesis unscathed. Conrad (1974), using the interference technique developed by Warren (1972), found other interesting data that may support the exhaustive computation hypothesis but, with these data as well, it is not possible to know whether the two senses of the ambiguous word are activated during the moment of processing or afterwards, as a result of the subsequent presentation of a biasing word. Thus, with the Warren technique as well, it is difficult to obtain information on the real-time processing of a sentence that is precise enough to choose between the two hypotheses.

With the phoneme-monitoring technique used by Foss (1970) and by Foss and Jenkins (1973), however, the precision of measurement at the moment of processing an ambiguous word is considerably greater. In the Foss technique a subject's task is to respond to the presence of a particular phoneme if it occurs at the beginning of a word. Since the presence of an ambiguous word may be expected to lead to more complicated processing, on the exhaustive computation hypothesis, the presence of an ambiguous word just before a target phoneme may be expected to lead to increased detection time, assuming that the time for detection of the phoneme just after an appropriate unambiguous word is also recorded for comparison. The results of Foss (1970) and Foss and Jenkins (1973) tend to fall into the pattern suggested by the exhaustive computation hypothesis; namely, that detection times just after an ambiguous word are significantly longer than just after an unambiguous word.

Results analogous to those of Foss were obtained by Cairns and Kamerman (1975) with the same technique. They also showed that the difference in reaction time disappeared when the word containing the target phoneme did not immediately follow the ambiguous word. This finding suggested to the authors that the effect of ambiguity is due to a necessary stage in the processing of ambiguous words, in which a decision must be made among its various senses, the sense chosen being transferred subsequently into working memory. This view is at odds with the view of Foss and Jenkins, in that in the latter's view, it is not just one sense that is transferred into working memory but the complete set of senses. Thus, on this latter view, the extra time required after ambiguous words is the result of an overloading of working memory and is not the result of a complicated decision process. In any case, Cairns and Kamerman agree with Foss that the presentation of an ambiguous word in a sentence causes the activation of all the different senses of the word.

Since these experiments strike us as the most solid evidence that exists to support the exhaustive computation hypothesis, it is therefore of considerable interest to ensure that the results are sound and incontestable. In this connection, it appeared that a possible artifact might exist as a result of a particular property of the sentences employed. In these experiments, the ambiguous/unambiguous variable for the words was partially confounded with the length of the words. In particular, this partial confounding had the specific effect that the ambiguous words were frequently shorter than the unambiguous words. This fact could pose problems for the interpretation of the results, for the length of the word just before the target phoneme might, on at least two plausible grounds, affect the reaction time for the target phoneme. The plausibility resides in the fact that a long word is generally a redundant word, in the sense that once the initial syllables are perceived, the amount of information provided by the final syllables is generally slight. Thus, in a sense, the processing of a long word can be effectively terminated before the final syllable has even been heard and thus, at the instant when a target phoneme is pronounced, a subject's momentary processing load is relatively light. With a short word, however, the low redundancy can result in a state of high processing load at the instant when the target phoneme is pronounced, a situation that could easily lengthen reaction time to the phoneme. While Foss and Jenkins noted that the unambiguous words employed were longer than the ambiguous words, and that this fact might cause reaction times for target phonemes to be shorter after unambiguous words, they considered that this fact should have only a slight effect, since, as a compensating factor, the frequency of the ambiguous words was higher, which would serve to shorten reaction times after these words. Although this reasoning is probably correct, it is not clear that the relative "weights" of the two factors length and frequency are equal, and thus it is not clear that the two factors were effectively counterbalanced in such a way that the ambiguous/unambiguous factor alone can be treated as the determining factor. It seemed likely that word length can play a fundamental role in the real-time processing of a sentence and thus, in the experiment reported here, the effect of the lexical ambiguity of a word was studied by varying word length and holding word frequency constant.

Materials and Procedure

Two sets of test materials were employed. Set A consisted of 15 pairs of French sentences, and Set B of 8 pairs. In every case the two sentences of a pair differed only in the test word that immediately preceded the target phoneme: In one sentence the test word was ambiguous, whereas in the other it was unambiguous. In Set A the ambiguous word and the corresponding unambiguous word had the same frequency in the French language [both having an intermediate frequency, i.e., an index between 0 and 10 according to the table of Gougenheim, Michea, Rivenc, and Sauvageot (1956)], and both words had the same length in syllables. In Set B, on the other hand, the ambiguous word was always one or two syllables longer than the corresponding unambiguous word, while both words had the same frequency. Examples of both kinds of pairs are presented and translated in Table 1, with the test words (which immediately precede the target phoneme) in italics.

Sentences containing ambiguous words were themselves ambiguous; sentences containing unambiguous words were themselves unambiguous. In both cases the test word is predictable from the context with only a very low probability.

Two experimental lists of sentences were prepared. Each list contained one and only one sentence of each pair. Each list included 23 test sentences (15 from Set A and 8 from Set B), of which 12 (or 11) were ambiguous and 11 (or 12) were unambiguous. In addition, each list contained 29 filler sentences, which were the same in each list. These filler sentences were introduced in order to allow the position of the target phoneme to vary within the sequence and also to have some sentences that did not possess the phoneme for which a subject was set to respond. The order of the 52 sentences in a list was random, but with the restriction that no more than two test sentences might follow in immediate succession at any point in a list.

TABLE 1

EXAMPLES OF THE EXPERIMENTAL MATERIALS

Set A		
	Ambiguous:	La dame a acheté une *glace* pour offrir à sa fille.
		(The lady bought *an ice cream* / *a mirror* to offer to her daughter.)
	Unambiguous:	La dame a acheté une *dinde* pour offrir à sa fille.
		(The lady bought a *turkey* to offer to her daughter.)
Set B		
	Ambiguous:	J'ai vu un film qui s'appelle "*L'héroïne* disparut à Hong-Kong."
		(I saw a film called "The *heroine* / *heroin* disappeared in Hong Kong.")
	Unambiguous:	J'ai vu un film qui s'appelle "Le *tigre* disparut à Hong-Kong."
		(I saw a film called "The *tiger* disappeared in Hong Kong.")

The target phonemes used were the occlusive consonants /p, b, t, d/, which were chosen on the basis of earlier results which showed that reaction times for these phonemes were shorter and less variable than reaction times for other phonemes (Savin & Bever, 1970; Rubin, Turvey, & Van Gelder, 1976).

The experimental lists were recorded by a male native speaker of French using a normal neutral intonation on a two-track Ampex AG 440B tape recorder at 15 ips, with 30 seconds between sentences. Each sentence was preceded by a specification of the phoneme to be detected in that sentence. In order to indicate the phoneme, a French city whose name begins with the phoneme was pronounced: "/p/ as in Paris," "/b/ as in Bordeaux," "/t/ as in Toulouse," "/d/ as in Dunkerque."

The experimental instructions indicated to a subject that he was to respond as rapidly as possible, by pressing on the response button, to a word beginning with the target phoneme. He was also asked to pay attention to the meaning of the sentences, for he was told that he would be questioned as to their content at the end of the experiment. This instruction was given in order to assure that subjects would comprehend the sentences. At two or three points determined at random the experimenter asked the subject to answer a simple question on the meaning of the sentence he had just heard. It was decided that if subjects failed to answer these questions correctly, they would be eliminated from the data analysis but, in fact, no failures occurred.

Subjects were run individually in connection with an Ampex Type AG 440B tape recorder that was controlled by a PDP-12 computer. When responding to the presence of the target phoneme, subjects pressed a response button that stopped a crystallized electronic clock in the computer, which has a maximum error of ± 1 millisecond. The clock was triggered by a click placed on the stimulus tape's second channel, isolated by more than 70 decibels from the stimulus sentences. The click was an extremely rapid electrical transition that activated the clock in less than 10 microseconds. The alignment of clicks with the beginnings of target phonemes was initially done manually, by running the tape slowly across the playback heads; subsequently, each alignment made in this way was realigned by means of an oscilloscope with two channels. Each time the oscilloscope located a discrepancy on n milliseconds, the program for collecting data on that target phoneme was instructed to adjust a subject's reaction time by n milliseconds. With these precautions, the only appreciable error remaining in the system was the uncertainty in locating the beginning of a word, which is of the order of half a cycle in the fundamental frequency of the voice, or roughly 5 milliseconds.

The design of the experiment, by making the target phoneme clear with the aid of the city–name mnemonic, tended to minimize the probability of false-alarm responses. When, in fact, a rare false alarm occurred, the computer program obtained highly anomalous data on the reaction time for that sentence, and all the data for that subject were eliminated from the data analysis. There were only two such subjects who produced false-alarm responses of this type. When reaction times of 1 second or longer were recorded, these data were eliminated from the data analysis, but the other data produced by the same subjects were retained. Less than 3% of the reaction times were longer than 1 second.

Subjects

Thirty-two adults in the Parisian university community served as subjects. They were between 18 and 40 years of age and had no particular sophistication in experimental psychology or linguistics. Sixteen subjects received the first list; the remaining 16 subjects received the second list. Each subject was paid 10 francs for his participation in the experiment, which lasted about 40 minutes.

Results

The mean reaction times in milliseconds for sentences in Sets A and B are presented in Table 2 as a function of ambiguity. The table shows that the mean reaction time for unambiguous sentences in Set A was slightly longer than for ambiguous sentences in the same set. This result, although statistically insignificant [$t(31) = 1.20$, $p > .10$], is opposed to that obtained by Foss and Jenkins (1973) and by Cairns and Kamerman (1975). As Table 3 suggests, a similar statistical analysis, treating pairs of sentences as a random variable, also failed to reveal a significant difference [$t(14) = 0.9$, $p > .10$]. As for Set B, however, the difference between ambiguous and unambiguous sentences was highly significant [$t(31)$

TABLE 2

Mean Reaction Times in Milliseconds for the Ambiguous and Unambiguous Sentences in Sets A and B

	Ambiguous	Unambiguous
Set A	406	419
Set B	400	460

TABLE 3

Mean Reaction Times in Milliseconds for Each of the Test Words in Each Pair of Ambiguous and Unambiguous Sentences

Set A		Set B	
Ambiguous words	Unambiguous words	Ambiguous words	Unambiguous words
Éclairs (441)	Bonbons (483)	Manoeuvres (389)	Tanks (451)
Palais (457)	Poignet (442)	Article (400)	Étoile (448)
Côte (471)	Fleuve (458)	Étalon (413)	Cible (419)
Mineur (357)	Libraire (392)	Pavillon (406)	Blé (500)
Pêche (446)	Pomme (446)	Avocat (300)	Gant (385)
Vol (395)	Match (417)	Général (430)	Soldat (399)
Poêles (469)	Lampes (412)	Héroïne (434)	Tigre (507)
Livres (372)	Cahiers (477)	Solution (387)	Cahier (417)
Glace (373)	Dinde (377)		
Marches (334)	Trajets (416)		
Pile (477)	Gomme (460)		
Carrière (364)	Emploi (352)		
Pièce (421)	Ruelle (317)		
Moules (447)	Frites (517)		
Dossier (369)	Armoire (422)		

= 3.21, $p < .01$], with ambiguous sentences taking significantly less time than unambiguous sentences. This result is directly at odds with the findings of the earlier researchers cited above. As Table 3 also suggests, statistical significance for this result appeared when pairs of sentences were treated as a random variable [$t(7) = 3.05, p < .05$].

Discussion

The results show, on the one hand, that if the frequency and the length of test words are controlled, the reaction time to a target phoneme immediately following is not determined by the ambiguous or unambiguous status of the test word. On the other hand, the reaction time is longer when a test word is short, and this effect is independent of the ambiguity or nonambiguity of the test word. These results show that the reaction time differences obtained by Foss and Jenkins (1973) and by Cairns and Kamerman (1975) may derive from an experimental artifact. It is most likely that in these earlier experiments the determining variable was the length of the test word, since the majority of the ambiguous test words were short. Our results suggest that when the covariance between ambiguity and length is eliminated, the length factor alone has a determining effect on reaction time to the target phoneme. Thus we are obliged to suggest that some of the evidence that others have used to support the exhaustive computation hypothesis and to infirm the unitary perception hypothesis is incorrect. Our results are compatible with the unitary perception hypothesis, according to which one computes, in general, a single semantic reading for an ambiguous word.

It is not our intention to present a complete account of the mechanisms involved in the processing of sentences, but it may be appropriate to remark that our data, as well as the data of Cutler (1976) concerning the role of predictable or abnormal intonation in phoneme monitoring, are consonant with the general assumptions of Foss (1970) and Foss and Jenkins (1973). The general model of attention sharing among all the various psycholinguistic levels, whereby attention to one level momentarily reduces the ability of a subject to pay attention to other levels, would seem to be appropriate for momentary attention to words of varying lengths. Long words are partially redundant words, and thus, at the end of a long word, a subject has more attentional capacity available for a phoneme-monitoring task than he has at the end of a short word. This pattern of responses has been replicated by Vipond (Note 1) in an as yet unpublished paper, and Vipond also favors an account of the phenomenon in terms of attentional capacity. An alternative interpretation for similar data has been proposed by Morton and Long (1976), who showed that the transitional probability of the word containing the target phoneme also contributes to the determination of the reaction time to the target phoneme. Whereas our tendency is to suggest that with long test words a subject has more spare capacity for detecting the target phoneme just after the test word, it is also possible to suggest, extrapolating Morton and Long's view, that with long test words a subject has more time to form hypotheses concerning the word to follow and thus to predict the target phoneme. These two hypotheses are not incompatible, and it may be possible to assess their relative merits in future research.

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