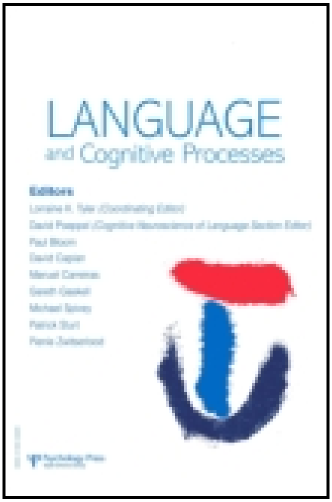

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Francois Grosjean
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Using Prosody to Predict the End of Sentences in English and French: Normal and Brain-damaged Subjects

François Grosjean and Cendrine Hirt

Laboratoire de traitement du langage, Université de Neuchâtel, Neuchâtel, Switzerland

In an earlier study (Grosjean, 1983), it was found that listeners of English were surprisingly accurate at predicting the temporal end of a sentence when only given the part up to the "potentially last word", that is a noun before an optional prepositional phrase of varying lengths. The present study investigated this phenomenon in four experiments. The first two experiments examined the prediction capabilities of listeners when presented with the whole sentence in segments of increasing duration and when presented with the potentially last word only. The results indicate that to be able to use prosody to predict the end of sentences correctly, subjects must have reached a point in the sentence where neither syntax nor semantics can contribute to the prediction process. The third experiment investigated whether the results obtained with English can be replicated in French, a language with a very different prosodic structure. It was found that unlike their English counterparts, French listeners were unable to differentiate between sentences that continued, although they could tell if a sentence ended or not. Finally, the fourth experiment examined whether left and right hemisphere brain-damaged (LHD, RHD) patients are equally proficient at estimating the length

Requests for reprints should be addressed to François Grosjean, Laboratoire de traitement du langage, Université de Neuchâtel, Avenue du Premier-Mars 26, 2000 Neuchâtel, Switzerland.

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of a sentence. LHD patients behaved like their controls, but RHD patients experienced great difficulty doing the task. This confirms that sentence prosody may well involve the right hemisphere, especially when no other type of linguistic processing is involved. The extension of these studies to other types of linguistic material and to other languages is discussed, as is the on-line use of prediction in language processing.

INTRODUCTION

The phenomenon of prediction during language processing, also known as anticipation, expectation, look ahead and forecasting, has not received much attention in speech perception and comprehension research. And yet it is an important phenomenon which becomes apparent when the listener gets ready to reply before the speaker is finished or when he or she actually finishes one of the speaker's sentences. In fact, in a normal conversation, prediction is pervasive and is shown by the fact that people rarely leave long gaps between exchanges but also rarely interrupt one another (Brazil, 1981). Prediction is facilitated by the structure of the language at all levels (discourse, semantic, syntactic, morphological and phonetic) and it is helpful in a number of ways. First, it can reduce the set of possibilities and therefore help focus the attention of the listener. This in turn makes processing more efficient and may at times accelerate it. Second, prediction can help demarcate or set up a domain of processing. It can, for example, mark a word boundary or a phrase or sentence boundary, so that the listener is ready for what is to come afterwards. And third, prediction can give the listener time for other activities such as integrating the information that has been processed, storing it, preparing a response, and so on.

Despite its obvious usefulness, prediction has not been integrated into many models of language processing contrary to its integration into general cognitive models such as those of timed events (e.g. Boltz, 1993; Jones, Boltz, & Klein, 1993). Several reasons account for this. One is that prediction is probabilistic in nature and it is only in more recent models of language processing that probability has been reinstated as an important feature of language structure and processing. Another is that models differ in when they allow prediction to take place. There is still much controversy about the number and types of stages involved in processing—two main stages (a perceptual stage followed by a post-perceptual or strategic stage) or just one stage involving considerable interaction among the processing levels {compare, for example, Forster (1979) and Fodor (1983) with Marslen-Wilson and Tyler (1987) and with McClelland and Elman (1986)}. Finally, there is as yet very little direct experimental evidence concerning prediction during processing.

One important source of prediction during processing is prosody. It can be used either to process the signal up to the point reached by the speaker (and hence by the listener) or to predict what is to come beyond that point. Regarding the first alternative, considerable work has been done to show how prosody can help process utterances (e.g. Lehiste, 1973; Scott, 1982; Speer, Crowder, & Thomas, 1993; Streeter, 1978; Wingfield, 1975). As for predicting later events, Martin and his colleagues (Martin, 1972; Meltzer et al., 1976; Shields, McHugh, & Martin, 1974) have shown with the help of various monitoring tasks how the listener ''locks into'' the stress pattern of the sentence and thus can anticipate upcoming stressed syllables and the end of the speech sequence (see also Buxton, 1983). Cutler, in a series of papers (Cutler, 1976; Cutler & Darwin, 1981; Cutler & Fodor, 1979; Cutler & Foss, 1977), has also shown that the prediction of upcoming accents is an integral part of sentence processing. With the help of various on-line tasks, she demonstrated that the listener will find the focus of the sentence by cueing in on the prosodic information carried by the first part of the sentence. Finally, and more recently, Beach (1991) has shown with the help of a discrimination task that listeners can use prosodic information to predict upcoming syntactic structure or to resolve syntactic ambiguity.

Grosjean (1983) was interested in studying how much sentence length information, conveyed by prosody, is available to the listener during sentence processing. An anecdotal observation triggered his study. Any listener of radio news programmes will have noticed from time to time that speakers who are interviewed are sometimes cut off midway through their utterance by the editor preparing the interview for broadcasting. A closer examination of the splicing points reveals that whereas the main syntactic and semantic boundaries are respected, the prosodic breaks are not. That is, the spliced utterance is grammatically correct and makes perfect sense but prosodic cues such as intonation, rate and rhythm tell the listener that the utterance is not over. In fact, the listener sometimes has the impression that the speaker said much more than was actually given. In order to assess the amount of information carried by prosody about the length of the sentence, Grosjean examined whether listeners who are only given the part up to the ''potentially last word'' of a sentence (in this case, a noun before an optional prepositional phrase) can indicate whether a sentence is over or not and, if it isn't, how much longer it will last. He used sentences that contained optional endings ranging in length from zero to nine words. For example, ''Earlier my sister took a dip'' could end on ''dip'' (+0 words) or could continue with ''. . . in the pool'' (+3 words), or ''. . . in the pool at the club (+6 words) or ''. . . in the pool at the club on the hill'' (+9 words). These sentences were gated on the object noun (e.g. ''dip''). Subjects heard each sentence up to the noun and then the noun in segments of increasing duration (see Grosjean, 1980, for a presentation of the gating paradigm),[1] and they had to choose which of the four sentences in a set was being presented. The results showed that the subjects were surprisingly accurate at predicting the length of the upcoming endings when basing themselves solely on prosodic cues. Although they could not differentiate between the four sentence types at the early gates, they became more and more proficient at doing so as they progressed through the word and, at the last gate (100% of the word), the estimated values were surprisingly close to the real values: sentences that stopped on the word (+0 words) were estimated to continue for 1.03 words on average; sentences with three-word endings were estimated to continue for 3.8 words; and those with six-word endings were estimated to continue for exactly 6.0 words. Only the nine-word endings were off the mark with subjects confounding them with six-word endings. The ‘‘fanning out’’ pattern of functions obtained as subjects progressed through the potentially last word (no differentiation at the beginning but good differentiation at the end, with the +0 word function dropping down to the 0 word level, the +3 word function remaining horizontal at 3 words, and the +6 and +9 word functions rising to the 6 words level) was replicated in a timing study in which subjects had to listen to the sentence fragments and to press a key when they thought the sentence would have ended had it been given to them in its entirety. Two potential artefacts—a ‘‘wait and see’’ strategy on the part of the subjects and the repetitive nature of the paradigm—were shown not to be involved. Finally, an acoustic analysis of the test sentences showed a strong relationship between measures of fundamental frequency (F0), amplitude and duration and the experimental data. F0 and duration were better predictors of the data than amplitude (see Streeter, 1978, for similar findings) and the values measured over the potentially last word only (i.e. the noun) were better predictors than those measured over the whole sentence (up to and including the noun but not the prepositional phrase afterwards).

Although Grosjean showed that listeners are very good at using prosodic information to determine whether a sentence is over or not when listening to the potentially last word of that sentence and to determine how much longer it will last when it is not over, his study also raised a series of questions that we will attempt to answer in this paper. First, can a subject predict the length of a sentence at any point within the sentence or must he or she be hearing the potentially last word of that sentence? In Grosjean’s study, the only word tested was the potentially last word. Linked to this are two subsidiary issues: Must the subject be hearing a stressed syllable to make an accurate prediction (as was the case in the original study) and does prediction get

[1]Despite some controversy on the on-line nature of the gating paradigm (see Grosjean et al., 1994), it is generally accepted that it is a good way of assessing how much information (segmental and prosodic) is available at a given point in time in a word, phrase or sentence.

better as the subject progresses through the sentence? Second, given that the predictive power of the acoustic variables measured on the potentially last word (the noun) was better than that of the variables measured on the whole sentence, can subjects differentiate between the various endings if they only hear the last noun? In Grosjean's study, subjects worked through the noun but were also given the prior context. How much information, then, is contained on the noun itself? Third, can the original findings be replicated in a language that has a very different prosodic structure, in this case, French? It is well known that French and English differ on such prosodic aspects as timing, F0 movement, pausing, etc. (for a summary, see Delattre, 1965; Vaissière, 1983), and it is therefore interesting to ask whether French listeners are as proficient as English listeners at predicting the length of a sentence. A final set of questions concerns brain-damaged patients. How do right and left hemisphere brain-damaged subjects react to prosodic information concerning the length of the sentence? Can both groups predict the end of a sentence equally well or is one group more proficient than the other as some studies would seem to suggest (Blumstein & Cooper, 1974; Bryan, 1989; Shipley-Brown et al., 1988)?

We attempt to answer these various questions in this paper. Experiment 1 examines the prediction capability of English-speaking subjects when working their way through the whole sentence. Experiment 2 studies prediction when subjects are presented with the potentially last word only. Experiment 3 is a replication of Grosjean's orignal study with French-speaking subjects, and Experiment 4 examines how French-speaking left and right hemisphere brain-damaged patients perform on the prediction task. It is clear that showing the listener's ability to use prosodic cues to predict the length of a sentence as it is being processed will have important consequences for models of sentence processing.

EXPERIMENT 1

In this experiment, we ascertained whether subjects can predict the length of a sentence at any point within the sentence or whether they must wait for the potentially last word of the sentence. Both outcomes are possible. On the one hand, the prosodic structure of the sentence is such that a lot of information is available from its beginning (declination line, F0 movement, decrease in amplitude, etc.). On the other hand, it is rare to find a point in the early part of a sentence where prosody is the only cue as to whether the sentence is continuing or not. Because syntax and semantics can inform the listener that the sentence is indeed continuing, at least for a certain amount of time, it could be that prosodic information on the length of the sentence is either not available or cannot be accessed by the listener during the first part of a sentence. This would mean that the length of a sentence can only be estimated when no other information is available (i.e. during the potentially last word of a sentence, just before optional prepositional phrases or complements). We therefore presented the original sentences used by Grosjean in segments of increasing duration up to and including the potentially last word. This allowed us to examine where exactly prediction becomes possible and to assess whether the listener must be hearing a stressed syllable to make an accurate prediction, and whether prediction gets better as he or she progresses through the sentence.

Method

Subjects. Forty-eight English-speaking students, with no reported speech or hearing defects, took part individually in sessions lasting 40 min.

Materials. Twenty-four of the 32 sentence exemplars originally used by Grosjean (1983) were chosen for this study. Each exemplar belonged to one of three types of sentences. The first type (the zero-word-ending type) was a six-word simple declarative sentence. It started with a sentential adverb and ended with an object noun. Its verb favoured but did not mandate a prepositional phrase and was therefore subcategorised as —NP (PP) (e.g. "Earlier my sister took a dip"). The second type of sentence (the three-word-ending type) was identical to the first except that it continued with a three-word prepositional phrase (e.g. "Earlier my sister took a dip in the pool"). Finally, the third type (the six-word-ending type) was again identical to the first except that it continued with a six-word prepositional phrase. Here a three-word phrase was embedded in the prepositional phrase of the three-word-ending type (e.g. "Earlier my sister took a dip in the pool at the club"). It should be noted that Grosjean's fourth type (the nine-word-ending type) was not used as it had not been differentiated from the six-word type in the original study.[2]

The original recordings of the 24 exemplars (eight different sentences, three endings of each) were digitised at a sampling rate of 10 kHz and gated by means of a PDP9 computer. For each exemplar, markers were first placed at the beginning of the sentence and at the end of the object noun, the

[2]In terms of prosodic (or performance) structure (Gee & Grosjean, 1983), the first sentence type was made up of three ϕ-phrases, with the first ϕ-phrase (e.g. "Earlier my sister") bundling with a group made up of a verb ϕ-phrase (e.g. "took") and an object ϕ-phrase (e.g. "a dip"). The additional ϕ-phrase of the second sentence type (e.g. "in the pool") bundled to the existing prosodic structure by left branching, as did the additional ϕ-phrase of the third sentence type (e.g. "at the club"). The three sentence types were read in one breath group with no silent pause inserted between any of the ϕ-phrases. The reader always placed a primary stress on the first word of the sentence (e.g. "Earlier") and a secondary stress on its last word (e.g. "dip", "pool" and "club", respectively). An acoustic analysis of the sentence types is presented in Grosjean (1983, pp. 519–524).

potentially last word (End PLW). All remaining material after this point was discarded (i.e. the +3 and +6 word endings). Intermediate markers were then inserted at the following points in the sentence: after the stressed syllable of the initial adverb (Mid Adv), after the adverb (End Adv), after the determiner (End Det), after the first stressed syllable of the noun (Mid N), after the noun (End N), after the monosyllabic verb (End Vb) and, finally, after the article preceding the final noun (End Art). Thus each sentence exemplar was represented by a presentation set of eight gates of increasing duration, each new gate being increased by a word or part of a word. For example, ‘‘Ear’’, ‘‘Earlier’’, ‘‘Earlier my’’, ‘‘Earlier my sis’’, ‘‘Earlier my sister’’, ‘‘Earlier my sister took’’, ‘‘Earlier my sister took a’’ and ‘‘Earlier my sister took a dip’’. Four experimental tapes were prepared. Each tape contained six presentation sets, two from each of the eight exemplars of each of the three sentence types. The sets were presented in random order and the same sentence never appeared twice on the same tape.

Procedure. Four groups of 12 subjects each were run, one group for each of the experimental tapes. The subjects were presented with six answer sheets, one for each presentation set. At the top of each sheet were the exemplars of the three sentence types that had the same beginning. Each exemplar was preceded by a letter ranging from ‘‘a’’ to ‘‘c’’. For example:

a. Earlier my sister took a dip.
b. Earlier my sister took a dip in the pool.
c. Earlier my sister took a dip in the pool at the club.

Below these was an array of numbered lines containing the letters ‘‘a, b, c’’ and a 1–10 confidence rating scale, where 1 was labelled ‘‘very unsure’’ and 10 ‘‘very sure’’. There were eight such lines in all. The subjects were asked to listen to each presentation set and to indicate after each individual presentation whether the sentence fragment that had been presented came from sentence a, b or c. To do this they were asked to circle the appropriate letter on the answer sheet and to indicate how sure they felt about their choice by circling a number on the scale. They were informed that each presentation set was based on just one sentence type ending. They were given time before each presentation set to read the three sentences in front of them.

Data Analysis. As in Grosjean (1983), the letter circled by each subject at each of the eight gates was transformed to a number: ‘‘a’’ corresponded to zero more words estimated to the end of the sentence, ‘‘b’’ to three more words and ‘‘c’’ to six more words. The confidence ratings given by subjects at each gate were also recorded. The results were averaged over items and over subjects and analyses of variance were run on the number of words estimated and on the confidence ratings.[3]

Results and Discussion

Figure 1 presents the estimated length of the sentence ending (in words) as a function of the way through the sentence for each of the three sentence types. As can be seen, the subjects increased their estimate of the length of the ending, whatever the sentence type, as they progressed through the sentence. In addition, the differentiation between the three endings started to occur at the end of the verb, especially for the +6 word ending. It was really only when the subjects heard the potentially last word of the sentence that they finally differentiated between the three sentences.

Two analyses of variance confirmed these observations. First, a main effect was found for way through the sentence {by subjects: $F(7,329) = 26.63$, $P < 0.001$; by items: $F(7,49) = 39.83$, $P < 0.001$}. This effect could be due to the fact that subjects are being influenced by the syntax and semantics as they are working their way through the sentence. Until the potentially last word, both are telling them that the sentence is indeed continuing and it is therefore difficult for them to base their answer solely on prosodic indices. Second, a main effect was found for ending {by subjects: $F(2,94) = 11.03$, $P < 0.001$; by items: $F(2,14) = 6.21$, $P < 0.05$}. A *post-hoc* analysis (means comparisons) showed a significant difference between the +0 word ending and the +3 word ending ($P < 0.05$) and between the +0 word ending and the +6 word ending ($P < 0.001$), but not between the +3 and the +6 word endings. Finally, and more importantly, a significant way through × ending interaction was found {by subjects: $F(14,658) = 21.44$, $P < 0.001$; by items: $F(14,98) = 17.96$, $P < 0.001$}. A *post-hoc* analysis showed the beginning of a differentiation at the end of the verb; the +0 word ending was different from the +3 word ending ($P < 0.05$) and from the +6 word ending ($P < 0.001$). The differentiation was reduced at the end of the article preceding the last noun (only the +6 word ending was different from the other two endings at the 0.001 level) but reached its final configuration at the end of the noun (End

[3]A few words are necessary to justify our way of recoding the data and our subsequent use of analysis of variance. Sentence length is by definition a continuous variable, whether it is measured in segmental units (number of syllables, words, constituents, etc.), in units of time (sec, msec, etc.) or, for written sentences, in units of length (centimetres, inches, etc.). We assumed that the subjects perceived the visual exemplars they were presented with as elements taken from a continuous scale. Converting these answers to numbers of words or syllables (depending on the study) and treating them as elements from a continuous scale was acceptable, therefore. As for the use of analysis of variance, it was considered suitable because the underlying scale of measurement appears to be continuous and the statistics were done on subject or item means which cover a wide range of possible values.

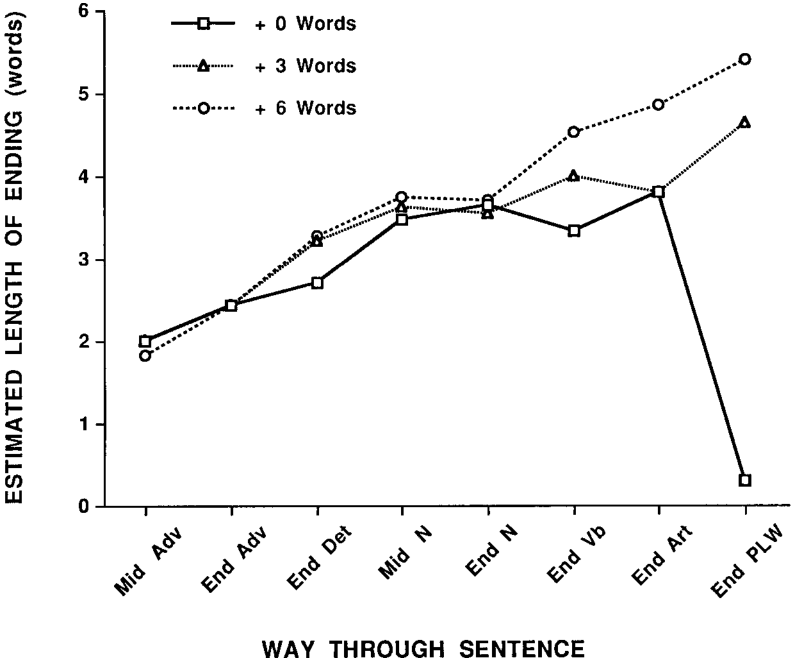

FIG. 1. Estimated length of the sentence ending (in words) as a function of the way through the sentence for each of the three sentence types. Each point is the mean of 96 observations, two by each of 48 subjects.

PLW), where every ending was different from the others (0.05 level or higher).

Confidence ratings produced a rather similar pattern. As the subjects worked their way through the sentence, their confidence ratings increased. At the first gate, the global mean was 2.1 and at the last gate it was 6.2. The ratings for the three endings remained similar up to the end of the article (End Art), but then the +0 word ending ratings suddenly increased. At the end of the noun (End PLW), the mean ratings for the +0, +3 and +6 word endings were 8.0, 5.2 and 5.4, respectively. Two analyses of variance confirmed these results. First, a main effect was found for way through the sentence {by subjects: $F(7,329) = 105.63$, $P < 0.001$; by items: $F(7,49) = 335.23$, $P < 0.001$}. Second, a main effect was found for ending {by subjects: $F(2,94) = 12.86$, $P < 0.001$; by items: $F(2,14) = 6.29$, $P < 0.05$}. A *post-hoc* analysis showed a significant difference between the +0 and the +3 word endings ($P < 0.001$) and between the +0 and the +6 word endings ($P < 0.001$), but not between the +3 and the +6 word endings. Finally, a significant interaction was found {by subjects: $F(14,658) = 27.01$, $P < 0.001$; by items: $F(14,98) = 28.49$, $P < 0.001$}. A *post-hoc* analysis showed the beginning of a differentiation at the end of the article for the +0 word ending that was different from the +3 word ending (4.7 and 4.1, $P < 0.001$) and from the +6 word ending (4.4, $P < 0.05$). At the end of the noun (End PLW), the +0 word ending was different from the +3 word ending ($P < 0.001$) and from the +6 word ending ($P < 0.001$), but the difference between the +3 and the +6 word endings did not quite reach significance ($P = 0.06$). Thus, the confidence rating results confirm that it is really only after hearing the last noun that subjects not only choose the appropriate ending correctly, but also feel more confident in their response (confidence rating above 5), especially if it concerns the +0 word ending.

Several points can be made based on these findings. First, the results obtained by Grosjean (1983) with subjects who only worked their way through the potentially last word were replicated in this study at the last gate (End PLW), although the estimated length of the +3 word ending was slightly higher than in that study. Second, by asking subjects to work their way through the whole sentence and not just the potentially last word, the longer ending (+6 words) began to be differentiated from the other endings during the last part of the sentence (after the verb). However, it was only during the potentially last word that the subjects clearly discriminated between the three endings (as in Grosjean, 1983), and were thus able to tell that the +0 word ending sentence was indeed terminating. Third, the prediction does not seem to be affected by the type of syllable that has just been heard: unstressed (e.g. End Adv, End Det and End N) or stressed (e.g. Mid Adv and Mid N). Finally, prediction did not progressively become better as the subjects worked their way through the sentence. In fact, it was only optimal after the potentially last word had been heard, although, as we saw above, the longer word ending does start to emerge on the preceding stressed syllable (the monosyllabic verb). Before accounting for these results, it is important to see how subjects manage with the prosodic information carried by the noun only.

EXPERIMENT 2

In this second experiment, we wished to assess whether listeners could differentiate between the three endings when listening simply to the potentially last word. In Grosjean (1983), subjects had always heard the sentence prior to the noun and in Experiment 1 they had worked their way through the sentence in gates of increasing duration. It was interesting to ask, therefore, whether subjects could differentiate the sentences by simply working their way through the noun. It is well known that words spliced out of the speech stream and presented to listeners are difficult to identify (Pollack & Pickett, 1963), but nevertheless the fact that Grosjean had found that the predictive power of the acoustic variables measured on the potentially last word was better than that of the variables measured on the whole sentence pointed to the possibility that enough prosodic information was contained on the noun to allow subjects to differentiate between various endings.

Method

Subjects. Twelve English-speaking students, with no reported speech or hearing defects, were tested individually in sessions lasting 20 min.

Materials. The 24 sentence exemplars chosen for Experiment 1 were used again, but this time only the potentially last word was presented in gates of increasing duration. For each word, three of the gates originally used by Grosjean (1983) were selected so that, for each sentence exemplar, the first stimulus corresponded to a gate at 20% of the way through the word (when a gate did not correspond to this figure, the gate closest to it was chosen), the second stimulus corresponded to a gate at or closest to 60% of the way through the word, and the last gate to 100% of the way through the word. Thus each of the 24 sentence exemplars was represented by a set of three word gates. One experimental tape was prepared that contained all presentation sets. The sets were randomised, but care was taken to separate by at least seven sets those that had the same word (e.g. "dip" from the +3 word exemplar was presented in position 1 and "dip" from the +0 word exemplar was presented in position 11).

Procedure. The subjects were presented with 24 answer sheets, one for each presentation set. The organisation of the sheets was the same as in Experiment 1 except that only three numbered lines and confidence rating scales were presented for each set. The subjects were given similar instructions but were also told that the task might not be very easy, as the segments were very short. They were again given enough time at the beginning of each set to become acquainted with the three sentences in front of them.

Data Analysis. The data analysis undertaken was the same as that in Experiment 1.

Results and Discussion

Figure 2 presents the estimated length of the sentence ending (in words) as a function of the way through the potentially last word for each of the three sentence types. As can be seen, the subjects showed the same "fanning out" pattern obtained in the original study and in Experiment 1, despite the difficulty of the task. As one would expect, the results were not as sharp as in

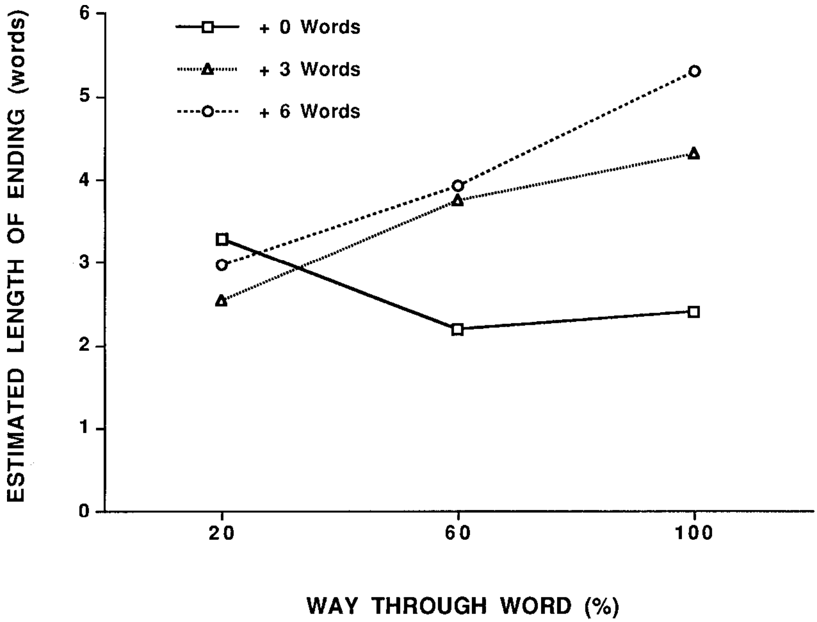

FIG. 2. Estimated length of the sentence ending (in words) as a function of the way through the potentially last word for each of the three sentence types. Each point is the mean of 96 observations, eight by each of 12 subjects.

the other studies and the +0 word function did not descend low enough (as compared to that in Experiment 1), but it is nevertheless clear that by the end of the word, the subjects could tell the difference between words spliced out of the +0, +3 and +6 word endings.

Two analyses of variance confirmed these observations. First, a main effect was found for way through the word {by subjects: $F(2,22) = 7.66$, $P < 0.01$; by items: $F(2,14) = 8.44$, $P < 0.01$}. This effect was largely due to the steady increase in the responses given to the stimuli from the +3 and +6 word sentences. Second, a main effect was found for ending {by subjects: $F(2,22) = 21.33$, $P < 0.001$; by items: $F(2,14) = 31.78$, $P < 0.001$}. A *post-hoc* analysis showed a significant difference between the +0 word ending and the +3 word ending ($P < 0.001$), between the +0 word ending and the +6 word ending ($P < 0.001$), and between the +3 word ending and the +6 word ending ($P < 0.05$). Finally, a significant interaction was found {by subjects: $F(4,44) = 10.95$, $P < 0.001$; by items: $F(4,28) = 13.60$, $P < 0.001$}. A *post-hoc* analysis showed no differentiation between any of the endings at 20% of the way through the word, but a significant difference ($P < 0.001$) between the +0 word ending and the other two endings 60% of the way through the word (not between the +3 and +6 word endings, however), and a significant difference between all endings at the end of the word ($P < 0.001$ between the

+0 word ending and the other two endings and $P < 0.01$ between the +3 word ending and the +6 word ending).

As in Experiment 1, confidence ratings produced a very similar pattern of results. The confidence ratings increased from the first to the last gate with overall means of 2.57 at 20% of the way through the word and 4.85 at 100% of the way through. The ratings of the +3 and +6 word endings rose more slowly than those of the +0 word ending. At 100% of the way through the word, the +0, +3 and +6 word endings had the following mean ratings: 5.56, 4.42 and 4.56, respectively. Two analyses of variance showed the following. First, a main effect was found for way through the word {by subjects: $F(2,22) = 20.77$, $P < 0.001$; by items: $F(2,14) = 346.89$, $P < 0.001$}. Second, a main effect was found for ending {by subjects: $F(2,22) = 18.96$, $P < 0.001$; by items: $F(2,14) = 20.41$, $P < 0.001$}. A *post-hoc* analysis showed a significant difference between the +0 and the +3 word endings ($P < 0.001$) and between the +0 and the +6 word endings ($P < 0.001$), but not between the +3 and the +6 word endings. Finally, a significant interaction was found {by subjects: $F(4,44) = 4.60$, $P < 0.01$; by items: $F(4,28) = 7.78$, $P < 0.001$}. A *post-hoc* analysis showed no differentiation between the endings 20% of the way through the word, but a significant difference ($P < 0.001$) between the +0 word ending and the other two endings 60% and 100% of the way through the word.

From the above we can conclude that the potentially last word of a sentence contains sufficient prosodic information to allow subjects to differentiate between various endings: +0 words, +3 words and +6 words. Acoustic measures on the stimulus words (Grosjean, 1983) had predicted such an outcome, but it had yet to be tested.

The picture that is starting to emerge from these experiments is that, despite the prosodic information available to them, subjects only become proficient at estimating the length of the ending of a sentence when they are listening to the potentially last word of that sentence. The one exception would be for sentences with long endings (+6 words), which start being differentiated from other sentences slightly before this point. Two reasons could explain this finding. The first is that the prosodic information necessary for estimating the end of a sentence is much richer on the potentially last word than in earlier parts of the sentence. However, despite the fact that Grosjean (1983) found that the acoustic measures taken on the potentially last word predicted his experimental findings better than the measures taken on the whole sentence, the latter were nevertheless good predictors. A second, more intriguing explanation, is therefore called for. It is that when syntax or semantics informs the listener that the sentence is continuing, then the prosodic information concerning sentence length is either not made available to, or cannot be accessed by, the listener. It is only when higher-level information is no longer present—that is, at points where neither the syntax nor the semantics mandate continuation—that prosodic information is made available or is called into play. At this point, listeners take into account the prosodic information carried by the sentence fragment and, in particular, by the potentially last word, and use it to estimate the length of what remains of the sentence.

EXPERIMENT 3

In this experiment, we turn to the prediction of the length of sentences in a different language, French. As is well known, English and French have very different prosodic structures (Delattre, 1965; Vaissière, 1983). French is predominantly a "syllable-timed" language and English a "stress-timed" language and this has important consequences for the prosodic structuring of sentences. In addition, the two languages have quite different F0 contours. For example, in declarative sentences, continuation is mainly expressed by falling contours in English but by rising contours in French, and the final fall occurs on the last stressed syllable of the sentence in English but starts on the first syllable of the final prosodic word in French. Furthermore, the longest syllable in the prosodic word is the stressed syllable in English, whereas it is the last syllable in French. Given these differences, we decided to run Grosjean's original study in French in order to see how French listeners predict the ends of sentences. We wondered whether they would be able to differentiate between sentences that ended and those that continued and, among the latter, whether they would be able to distinguish short endings from long endings. Our expectations were mixed. On the one hand, we expected similar results to those obtained in English, as the two languages are governed by similar global prosodic characteristics (length of breath groups, general F0 declination, final sentence lengthening, etc.). On the other hand, we thought that the many prosodic differences between the two languages would lead French listeners to behave somewhat differently.

Method

Subjects. Thirty-two French-speaking students, with no reported speech or hearing defects, were tested individually in sessions lasting 30 min.

Materials. Thirty-two sentence exemplars were used in the experiment. As in Grosjean (1983), each exemplar belonged to one of four types of sentences. The first type (the zero-syllable-ending type) had a structure similar to the one used in English: it was a simple declarative sentence, starting with an adverbial complement and ending with an object noun. Its verb favoured but did not mandate a prepositional phrase; for example, "Avant-hier, le garçon a volé un porte-monnaie" ("The day before yesterday, the boy stole a wallet"). The adverbial complement could be one or two words long but was always three syllables long. The object noun was also three syllables long (instead of one syllable in the original English version), so as to allow the study of the fanning-out effect on the last word. It should be noted that the unit of length in this study was the syllable, as elision phenomena in French complicate word counts. The second type of sentence (the three-syllable-ending type) was identical to the first except that it continued with a three-syllable prepositional phrase; for example, ''Avant-hier, le garçon a volé un porte-monnaie dans la cour'' (''The day before yesterday, the boy stole a wallet in the yard''). Again because of elision phenomena, the prepositional phrases (in this sentence type and in the following ones) did not all have the same number of words (which ranged from two to three) but they did have the same number of syllables (three, like their English counterparts). The third type of sentence (the six-syllable-ending type) was also identical to the first except that it continued with a six-syllable prepositional phrase; for example, ''Avant-hier, le garçon a volé un porte-monnaie dans la cour de l'école'' (''The day before yesterday, the boy stole a wallet in the yard of the school''). Finally, the fourth type (the nine-syllable-ending type) continued with a nine-syllable prepositional phrase; for example, ''Avant-hier, le garçon a volé un porte-monnaie dans la cour de l'école de la ville'' (''The day before yesterday, the boy stole a wallet in the yard of the school of the town'', better translated as ''The day before yesterday, the boy stole a wallet in the school yard of the town's school'').

The 32 sentence exemplars were recorded by two female speakers who were asked to read each exemplar in one breath group with no breaks. Two voices were used in order to bring diversity to the readings. Speaker 1's readings of the second half of the exemplars of each sentence type were discarded, as were Speaker 2's readings of the first half of the exemplars. Thus, the 32 exemplars were equally divided among the two speakers. The recordings were digitised with MacAdios at a sampling rate of 10 kHz and then gated. It was decided to gate not only the potentially last word (the object noun) but also slightly before it. Thus, the first gate corresponded to the sentence all the way to the end of the verb (End Vb; e.g. ''Avant-hier, le garçon a volé''), the second segment included the following determiner (End Det; e.g. ''Avant-hier, le garçon a volé un'') and the next four gates included increasing segments of the noun, that is the potentially last word: 25% PLW, 50% PLW, 75% PLW and 100% PLW. Each exemplar was thus represented by a presentation set of six gates. Four experimental tapes were prepared. Each tape contained eight presentation sets, two from each of the eight exemplars of each of the four sentence types. The sets were presented in random order and the same sentence never appeared twice on the same tape.

Procedure. Four groups of eight subjects were run, one group for each of the experimental tapes. The subjects were presented with eight answer sheets, one for each presentation set. The sheets were similar to those used in Experiment 1 except that four alternatives were given instead of three and there were six lines for the answers instead of eight. The instructions were given in French.

Data Analysis. The data were analysed as in Experiment 1 except that the letters (a, b, c, d) were transformed to a number of syllables: 0, 3, 6 and 9, respectively. Similar analyses of variance were run.

Results and Discussion

Figure 3 presents the estimated length of the sentence ending (in syllables) as a function of the way through the sentence for each of the four sentence types. First, there was a clear distinction between the +0 syllable ending and the other three endings. Not only was the +0 syllable function slightly lower than the other three functions in the early gates, but after the 50% PLW mark, it fell rapidly to the +0 syllable level (mean of 0.47 syllables at the last gate), whereas the others kept rising. Second, there was no distinction

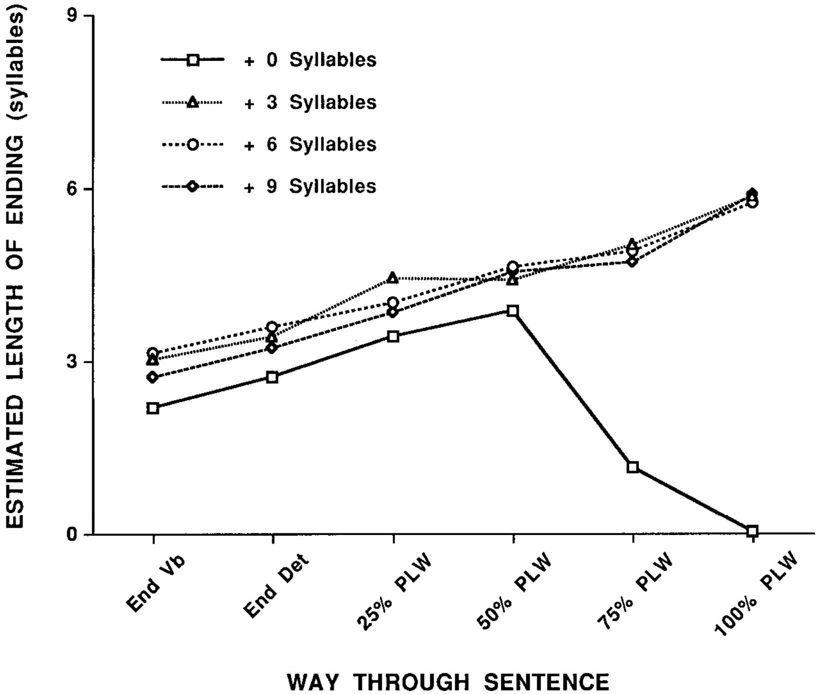

FIG. 3. Estimated length of the sentence ending (in syllables) as a function of the way through the sentence for each of the four sentence types. Each point is the mean of 64 points, two by each of 32 subjects.

between the +3 syllable, +6 syllable and +9 syllable endings. They all ended with similar values: means of 5.86, 5.77 and 5.91, respectively. It would appear, therefore, that French listeners can differentiate between sentences that stop and sentences that continue, but cannot do so for sentences that continue for differing amounts of time. They can neither discriminate between the +3, +6 and +9 syllable endings nor break them down into two large categories as do their English counterparts: sentences that continue for a short time and sentences that continue for a longer time.

Two analyses of variance confirmed this. A main effect was found for way through {by subjects: $F(5,155) = 25.91$, $P < 0.001$; by items: $F(5,35) = 25.26$, $P < 0.001$}, indicating a general rise in the length of the predicted endings. Another main effect was found for ending {by subjects: $F(3,93) = 17.26$, $P < 0.001$; by items: $F(3,21) = 17.98$, $P < 0.001$}, but a *post-hoc* test showed that it was only due to the +0 syllable ending being significantly different from the other three endings ($P < 0.001$), whereas the latter were not different from one another. Finally, an interaction was found {by subjects: $F(15,465) = 30.95$, $P < 0.001$; by items: $F(15,105) = 15.58$, $P < 0.001$}. A *post-hoc* analysis at each gate showed the following differences between the +0 syllable ending and the other endings ($P < 0.05$ or less): End Vb, +3 and +6; End Det, +3 and +6; 25% PLW, +3 and +6; 50% PLW, +3 and +9; 75% and 100% PLW, all three endings.

Confidence ratings brought converging evidence to these results. The overall confidence ratings increased from the first to the last gate. The global means were 3.37 at the End Vb point and 7.5 at the 100% PLW point. The ratings for the four endings remained very similar until the 50% PLW point and then those of the +0 syllable ending started to increase substantially. They reached a mean of 6.98 at the 75% PLW point and a mean of 9.25 at the 100% PLW point, whereas the other three endings climbed to global means of 5.44 and 6.95 at these two points. Two analyses of variance showed the following. A main effect was found for way through {by subjects: $F(5,155) = 124.55$, $P < 0.001$; by items: $F(5, 35) = 264.23$, $P < 0.001$}. Another main effect was found for ending, but by subjects only {$F(3,93) = 7.60$, $P < 0.001$; by items: $F(3,21) = 1.1$, NS}. A *post-hoc* analysis on the by subjects ANOVA showed that the +0 syllable ending was different from the other three endings and that the latter were not different from one another. Finally, an interaction was found {by subjects: $F(15,465) = 17.17$, $P < 0.001$; by items: $F(15,105) = 4.59$, $P < 0.001$}. A *post-hoc* analysis at each gate showed that the +0 syllable ending started to be different from the others at the last two gates (75% PLW and 100% PLW; all differences at the $P < 0.001$ level).

In order to give a better understanding of our results and, in particular, the lack of differentiation between the different types of sentences that continue after the potentially last word, we undertook an acoustic analysis of the 32 exemplars with the MacSpeech Lab program. As in Grosjean (1983) we measured three variables—fundamental frequency (F0), amplitude and duration—over two domains: the sentence domain which included all the words in the sentence up to and including the potentially last word (but not the various endings) and the potentially last word (PLW) domain. We adopted an approach similar to Grosjean's for each of the three variables. For the sentence domain, the F0 value obtained was the difference between the F0 peak of the last vowel of the first word of the sentence and the F0 peak of the last vowel of the PLW; the amplitude value was the difference between the amplitude peak of the last vowel of the first word and the amplitude peak of the last vowel of the PLW; and the duration value was the difference between the onset time of the first word and the offset time of the stimulus word. For the PLW domain, the F0 value was the difference between the F0 peak of the first vowel and the F0 peak of the last vowel of the word; the amplitude value was the amplitude of the last vowel of the PLW; and the duration value was the actual duration of the PLW.

Two one-way analyses of variance, one on the sentence fragment domain and one on the PLW domain, were conducted for each of the acoustic measures. The results for the sentence domain showed a main effect for F0 {$F(3,21) = 24.00$, $P < 0.001$} and for duration {$F(3,21) = 9.61$, $P < 0.001$}, but not for amplitude {$F(3,21) = 2.08$, NS}. *Post-hoc* analyses on the F0 and duration means showed a significant difference between the +0 syllable ending and the other three endings (+3, +6 and +9 syllables), but no difference among the +3, +6 and +9 syllable endings. A similar pattern of results was obtained for the PLW domain: a main effect for F0 {$F(3,21) = 9.58$, $P < 0.001$}, for duration {$F(3,21) = 17.91$, $P < 0.001$} and, this time, also for amplitude {$F(3,21) = 3.09$, $P < 0.05$}. *Post-hoc* analyses on the F0 and duration measures showed once again a significant difference between the +0 syllable ending and the other three endings, but no differences among the latter. As for amplitude, no pair differences reached significance.

We are now in a position to understand better the prediction results obtained. As no difference was found between the +3, +6 and +9 syllable endings on any of the three prosodic measures, whereas the +0 syllable ending was markedly different from the other endings, it is not surprising that the subjects could not differentiate between the sentences that continued. Listeners have to use prosodic values to differentiate between sentences that carry no other cues (syntactic or semantic) as to their length and when the prosodic values are not different, their prediction task is rendered impossible. To conclude, listeners of the two languages, English and French, behaved differently in this prediction task not for reasons linked to different psycholinguistic processes or strategies they might adopt, but simply because the information given to them by the prosody of their respective language is different. Prosody in English allows listeners to categorise sentences into three groups (those that stop, those that continue for a short while and those that continue for a bit longer), whereas prosody in French only allows listeners to categorise sentences into two groups (those that stop and those that continue).

EXPERIMENT 4

This last experiment examined how French-speaking left and right hemisphere brain-damaged patients perform on the prediction task. Much of the literature on the lateralisation of prosodic processing in normals and brain-damaged patients concerns word stress. However, opinion is divided as to the hemispheric dominance of stress processing, since the latter involves both prosodic and linguistic information (see, for example, Behrens, 1985; Blumstein & Goodglass, 1972; Bryan, 1989; Bradvik et al., 1991; Weinraub, Mesulam, & Kramer, 1981). Much less is known about the hemispheric processing of general sentence prosody; that is, the kind of prosody needed to predict the end of sentences, among other things. Two studies in which normal subjects were asked to identify various types of contours arrived at very similar conclusions. Blumstein and Cooper (1974) stated that normal language perception may involve the simultaneous analysis of the linguistic input in both hemispheres: processing of the linguistic or structural components of language (phonetic, syntactic, semantic) would be conducted primarily in the left hemisphere, whereas the analysis of the intonational components of speech would be conducted primarily in the right hemisphere. Similarly, Shipley-Brown et al. (1988) stated that the right hemisphere may be more adept at processing the prosodic elements of language than the left hemisphere. In a study involving brain-damaged subjects, Bryan (1989) found that right-hemisphere-damaged patients made significantly more errors on the prosodic tests given to them than left-hemisphere-damaged patients, one of the tests being the discrimination of question and statement contours.

Based on these findings, we can expect right-hemisphere-damaged patients to have more difficulty predicting the end of sentences than left-hemisphere-damaged patients. This hypothesis is reinforced by the fact that we used full sentence segments, that is segments with the potentially last word presented in full. At this point in the sentence, only prosodic cues can help the listener to decide whether a sentence is continuing or not. No help can be obtained from syntactic or semantic information, which would call upon the left hemisphere.

Method

Subjects. Ten patients with right hemisphere damage (RHD), 10 with left hemisphere damage (LHD) and 20 controls (the latter with no history of previous cerebral disorder or hearing loss) took part in the study. Each patient was paired with a control subject for age (plus or minus 3 years) and sex. The mean age of the RHD patients was 53.9 years and that of the 10 paired controls 56.0 years; the mean age of the LHD patients was 55.5 years and that of the paired controls 55.1 years. The patients and controls were all right-handed and were all native speakers of French. All the patients, with the exception of one who underwent a craniotomy, were unilaterally brain-damaged as a result of a cerebral vascular accident (CVA) as indicated by a neurological examination and/or a CT-scan/MRI {conducted at the Lausanne University Hospital (CHUV), together with a neuropsychological examination}. The RHD patients had no language problems but did have various neuropsychological disturbances, whereas all the LHD patients had both language and neuropsychological problems, the latter being of a different nature from those of the RHD patients. Neither group showed any evidence of general cognitive impairment or hearing and vision problems. A detailed description of the 20 brain-damaged patients is presented in the Appendix.

Materials. The complete segments (100% PLW) of the sentence exemplars of the zero-, three- and six-syllable-ending types in Experiment 3 were used in this experiment. These 24 segments were recorded in random order on tape.

Procedure. All the subjects (patients and controls) were tested individually. Instructions were given orally and responses were obtained by asking the subjects to point to one of three horizontal bars on a sheet of paper. The first bar, 8 cm long, was totally darkened (filled) and represented a sentence that had ended. The second bar, of the same length, was also filled but had an extra unfilled section attached to it on its right (2 cm in length). It represented a sentence that continued for a few more words. Care was taken to keep the same proportion of filled and unfilled parts as there were syllables in the auditory part of the sentence and in its unheard ending. Finally, the third bar was like the second bar except that the unfilled section added another 4 cm to the filled bar. It represented a sentence that continued for several more words. It was explained to the subjects that the sentence segments they would be hearing either ended on the last word or continued for a while (short or long), that they would not hear the last part of the sentences that continued, and that they had to point to the bar that best depicted what they thought they were hearing. Care was taken to make sure that the subjects understood the instructions before running the study.

Data Analysis. As in the other experiments, each answer was converted to a numerical value (0, 3 or 6 syllables) and the results were averaged over items and over subjects. Separate analyses of variance were conducted for the RHD patients and their controls and for the LHD patients and their controls.

Results and Discussion

Figure 4(a) presents the estimated length of the sentence ending (in syllables) as a function of the three sentence types (+0, +3 and +6 syllables) for the LHD patients and their controls. As can be seen, the LHD patients gave very similar responses to those of the controls. Like the controls, they were able to tell that the +0 word ending sentence was over and that the +3 and +6 word ending sentences were continuing, but they could not differentiate between the latter two. This was confirmed by two analyses of variance. There was no group main effect {by subjects: $F(1,18) = 2.34$, NS; by items: $F(1,14) = 1.84$, NS}; however, there was an ending effect {by subjects: $F(2,36) = 328.28$, $P < 0.001$; by items: $F(2,28) = 293.65$, $P < 0.001$} as well as an interaction {by subjects: $F(2,36) = 5.47$, $P < 0.01$; by items: $F(2,28) = 4.87$, $P < 0.05$}. To understand the interaction, we conducted *post-hoc* tests and found no difference between the two groups at the +0 syllable ending and at the +3 syllable ending. However, we did find a difference between the two groups at the +6 syllable ending. Because neither group showed a significant difference between the means of the +3 and +6 syllable endings, the inter-group difference at the +6 syllable ending was surprising, especially since no prosodic difference had been found between the +3 and +6 syllable endings in the acoustic measures in Experiment 3. It can perhaps be attributed to the beginning of a strategy of underestimating on the part of the LHD subjects. Despite this small difference between the two groups, the results of the LHD patients are remarkably similar to those of the controls, indicating that despite their aphasia they can continue to differentiate between a sentence that ends and one that continues.

Figure 4(b) presents the estimated length of the endings for the RHD patients and their controls. As is clearly evident, the patients had great difficulty with the estimation task. Not only did they overestimate the length of the +0 syllable ending (mean of 1.58 syllables as compared to a mean of 0 syllables for the controls), but they also underestimated the length of the +3 and +6 syllable endings (means of 2.85 and 2.74, respectively, as compared to 3.79 and 3.64 for the controls). Two analyses of variance confirmed these results. Although there was no group main effect {by subjects: $F(1,18) = 0.11$,

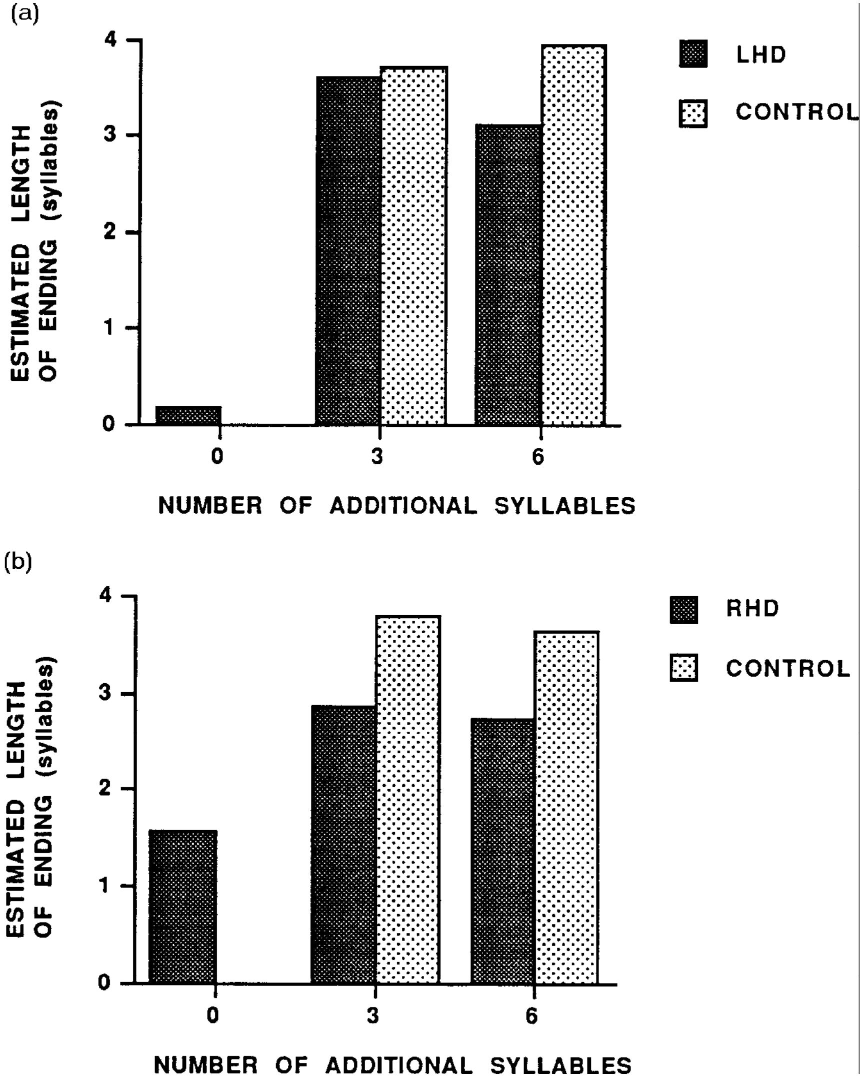

FIG. 4. Estimated length of the sentence ending (in syllables) as a function of the three sentence types for the LHD patients and their controls (a) and for the RHD patients and their controls (b). Each bar is the mean of 80 observations, eight by each of 10 subjects.

NS; by items: $F(1,14) = 0.11$, NS}, there was a main effect of ending {by subjects: $F(2,36) = 115.13$, $P < 0.001$; by items: $F(2,28) = 104.93$, $P < 0.001$} as well as a strong interaction {by subjects: $F(2,36) = 29.4$, $P < 0.001$; by items: $F(2,28) = 26.78$, $P < 0.001$}. A *post-hoc* analysis showed a significant difference between the group means at each of the three endings ($P < 0.05$).

We conclude from this experiment that the hypothesis put forward by Blumstein and Cooper (1974) and Shipley-Brown et al. (1988) is confirmed: the analysis of sentence prosody may well involve the right hemisphere, especially when no other type of linguistic processing is involved. It also brings converging evidence to Bryan's (1989) study, in which right-hemisphere-damaged patients made more errors on prosodic tests than left-hemisphere-damaged patients.

GENERAL DISCUSSION

We have been able to answer the four questions posed at the beginning of this paper. The first was whether English listeners could predict the end of a sentence at any point within the sentence, or whether they had to wait for a potentially last word. In Experiment 1, we showed that the longer endings (+6 words) started to be differentiated from the others (+0 and +3 word endings) before the potentially last word, but that it was only during the last word that listeners clearly discriminated between the three endings and could tell that the +0 word ending sentence was indeed coming to an end. In addition, it became apparent that prediction does not depend on whether the subject is hearing a stressed syllable or not, and that prediction does not progressively become better as subjects work their way through the sentence.

The second question we asked was whether listeners would be able to differentiate between the various endings if they only heard the last noun—that is, the potentially last word of the sentence. Experiment 2 showed that this was indeed the case and that the potentially last word contained sufficient prosodic information to allow subjects to differentiate between the +0, +3 and +6 word endings. In order to explain the results obtained in the two experiments, it was hypothesised that, in English, when syntax or semantics informs the listener that the sentence is continuing, then the prosodic information concerning the length of the sentence is either not made available to, or cannot be accessed by, the listener (with the possible exception of longer endings). It is only when higher-level information is no longer present—that is, at points where neither the syntax nor the semantics mandates continuation—that prosodic information is made available or is called into play.

The third question we asked was whether the original findings of Grosjean (1983) in English could be replicated in French, a language that has a very different prosodic structure. Experiment 3 showed that this was not the case. Although listeners clearly distinguished the +0 syllable ending from the other three endings (+3, +6 and +9 syllables), they could not differentiate between the latter. This was due to the fact that these three types of sentences were not different on any of the prosodic measures (F0, duration and amplitude). An additional finding of interest was that the +0 word ending was identified earlier on, during the preceding verb. This pattern is quite different from English, where the listener must wait for the potentially last word to perceive that a sentence is ending. Thus the prosodic organisation of the two languages produces different prediction results. English listeners can categorise sentences into three groups (those that stop, those that continue for a short while and those that continue for a bit longer) but, with the exception of the longer endings (+6 words), they have to wait until the potentially last word to do so. French listeners, on the other hand, can only categorise sentences into two groups (those that stop and those that continue), but seem to be able to do so earlier than the potentially last word. It would appear, therefore, that the listeners of the two languages behave differently not for reasons linked to different psycholinguistic processes or strategies they might adopt, but because the information given to them by the prosody of their respective language is different.

Finally, the last question asked was whether right hemisphere and left hemisphere brain-damaged subjects are equally proficient at estimating the length of a sentence. Experiment 4 showed a clear difference between the two. The left-hemisphere-damaged patients behaved similarly to controls in that they could differentiate the +0 syllable ending from the other two endings (+3 and +6 syllables) but could not distinguish between the latter two. The right-hemisphere-damaged patients, on the other hand, had great difficulty estimating the ends of sentences: not only did they overestimate the length of the +0 syllable ending, they also underestimated the length of the +3 and +6 syllable endings. It was concluded that the analysis of sentence prosody may well involve the right hemisphere, particularly when no other type of linguistic processing is involved.

The results of the present study and those of Grosjean (1983) show that there is enough prosodic information for the prediction of sentence length to take place and that listeners can be quite accurate in their prediction, but they do not show that prediction is a process that is an integral part of language processing. It is important, therefore, to produce direct evidence that the prediction of sentence length is indeed used during on-line speech processing. Given the considerable amount of structural and prosodic information contained in speech at a particular point in time about what is to come later, from phonetic information to discourse information, it would be surprising if prediction of sentence length did not occur during processing, but this still has to be shown by means of on-line techniques. If it can be, the process will have to be integrated into models of language processing as few, if any, make room for it currently. One way of doing this would be to include a length prediction device that would base itself on the prosodic information contained in the sentence and on some segmental information (such as syntactic structure). This prediction would be updated as the sentence unfolded and the device's information would be made available to the processes needing it. Included among these would be those involved with perception and comprehension (the syntactic parser, the semantic and pragmatic modules, etc.) as well as those involved with production so as to allow for optimal turn-taking (Brazil, 1981). One would also need to define how often the device resets itself (one suggestion is at every breath group), what its prediction units are (linguistic units such as syllables, phonological words or phrases, or temporal units such as seconds) and how these units are organised. Previous research by Martin (Martin, 1972; Meltzer et al., 1976; Shields et al., 1974) and by Cutler (Cutler, 1976; Cutler & Darwin, 1981; Cutler & Fodor, 1979; Cutler & Foss, 1977) favours a hierarchical structure of prosodic units, such as the one proposed by Gee and Grosjean (1983).

Future research on the use of prosody to predict sentence length needs to address a number of other issues. One of these concerns whether the results obtained so far with English and French can be extended to other spoken languages with different prosodic configurations (tones, for example) and to sign languages. Another relates to whether prediction is affected by such variables as the length of the sentence (recall that very long endings could not be predicted in English), its grammaticality (is prediction possible early on in English when ungrammatical strings of words are read with normal prosody?), the syntactic complexity of the sentence, its type (interrogative, negative, passive), etc. A third issue concerns spontaneous speech. All the experiments so far (those in Grosjean, 1983, and the four in this paper) were conducted with read-out speech. One might ask whether similar results would be obtained with sentences produced spontaneously. One approach would be to find sentences in spontaneous interviews that are similar to the ones used here (that is, sentences with adverbial or prepositional phrases) and to splice them at the same critical point. If the auditory effect produced by poorly spliced radio or television interviews is any evidence, we should obtain results that are similar to those produced with read-out speech.

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APPENDIX

Description of the brain-damaged patients in Experiment 4

Patient	*Sex*	*Age*	*Lesion Localisation*	*Major Neuropsychological Signs*	*Token Test Score (%)*
Left-hemisphere-damaged group					
1	M	64	Fronto-temporoparietal	Global aphasia	42
2	M	67	Fronto-temporoparietal	Mild residual signs of transitory global aphasia	95
3	F	58	Parietal	Atypical fluent aphasia, severe word retrieval difficulties	50
4	M	69	Unknown	Global aphasia developing into Broca's aphasia	50
5	M	51	Fronto-temporoparietal, putaminal lesion	Atypical non-fluent aphasia	75
6	F	42	Territory of the anterior cerebral artery	Residual signs of transcortical motor aphasia	72
7	M	48	Temporoparietal	Residual signs of anomic aphasia	95
8	F	59	Temporoparietal, subcortical lesion	Conduction aphasia	92
9	F	53	Frontotemporal, insula	Transcortical mixed aphasia developing into anomic aphasia	53
10	M	44	Fronto-temporoparietal	Severe global aphasia	3
Right-hemisphere-damaged group					
1	M	76	Subcortical frontoparietal	Memory disorders, signs of frontal dysfunction	
2	M	36	Subarachnoidal haemorrhage	Memory disorders, poor abstraction, signs of frontal dysfunction	
3	M	57	Fronto-temporoparietal	Moderate signs of right hemisphere damage	
4	M	37	Territory of the anterior cerebral artery	Signs of frontal dysfunction, unilateral spatial neglect	
5	M	37	Subcortical frontal	Mild memory disorders, poor verbal fluency	
6	F	48	Fronto-basal	Unilateral spatial neglect, signs of frontal and visuospatial dysfunction	
7	M	48	Subarachnoidal haemorrhage	Signs of frontal and visuospatial dysfunction	
8	F	76	Fronto-temporoparietal	Unilateral spatial neglect, signs of right hemisphere damage	
9	F	50	Fronto-temporoparietal	Signs of frontal dysfunction, unilateral spatial neglect	
10	M	74	Territory of the posterior cerebral artery	Signs of right hemisphere damage	