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Syntactic Ambiguity Resolution While Reading in Second and Native Languages

C. Frenck-Mestre and J. Pynte

CREPCO, University of Provence, National Centre for Scientific Research, Aix-en-Provence, France

Bilinguals' reading strategies were examined in their native and second language via the recording of eye movements. Experiment 1 examined the processing of sentences that contained local syntactic ambiguities. Results showed that bilinguals reading in their second language tended to resolve these ambiguities in a different way from native readers. Bilinguals tended to prefer to attach incoming information to the most recently processed constituent. However, this global strategy was influenced by lexical information provided by the verb. Moreover, the combined analysis of both groups of readers revealed an influence of verb subcategorization information on syntactic ambiguity resolution. Experiment 2 also examined syntactic ambiguity resolution in the native and second language, for sentences that were ambiguous in only one of the bilinguals' two languages. Results showed that bilinguals hesitated when reading in their second language at points in the sentence where their native language presented conflicting lexical information. Following this localized effect of "transfer", however, bilinguals performed in a manner similar to native speakers of the language. In combination, these experiments demonstrate that bilinguals perform a complete syntactic parsing of sentences when reading in the second language, and they do so in a manner similar to native speakers. Although lexical information can apparently influence parsing in the second language, our results do not provide strong evidence that it acts to override syntactic analysis based on structural principles.

As most adults who have attempted to master a second language after early childhood would agree, reading in a second language is anything but an automatic process. The difficulty associated with foreign-language reading is reflected in the results of various bilingual studies of sentence processing using a wide variety of measurements, from simple reaction time (Mack, 1986), to on-line assignment of grammatical roles (Kilborn, 1989), to the recording of evoked potentials (Ardal, Donald, Meuter, Muldrew, & Luce, 1990). Unanimously, these studies have shown that not only is second-language processing slower than native-language processing, but the pattern of results observed for

Requests for reprints should be sent to C. Frenck-Mestre, CREPCO–Université de Provence, 29 av. Robert-Schuman, 13621 Aix-en-Provence, Cedex, France. E-mail: frenck@romarin.univ-aix.fr

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bilinguals when analysing sentences in their second language is qualitatively different from that obtained for native speakers of the language.

Second-language processing apparently differs from native-language processing in several ways. For example, a study of text comprehension in the native (L1) and second (L2) language of advanced second-language learners (Kozminsky & Graetz, 1986) revealed that when reading a text, these subjects underlined key words in the L2 text, as opposed to complete phrases in the L1 text, and they annotated the L2 text rather than simply mark passages, whereas they did the opposite in the L1. When summarizing the same texts, these subjects were less likely to paraphrase and followed paragraph order more for L2 than L1 texts. The results of this study led its authors to claim that text-summarizing reflects "word-focus orientation" in the second language, as opposed to performance in the native language, which reflects greater influence of the text's macro structure. It has also been suggested that bilinguals may be less sensitive to syntax in their second language than in their native language (where syntactic processing is presumably more automated) and that second-language processing is more conceptually than syntactically guided (Ulijn, 1980).

Whereas the above studies suggest the development of processing strategies specific to the second language, a considerable body of research has focused on the interactions between the native and the second language. In particular, the question has been raised as to whether adult, late bilinguals (those who learned their second language after puberty) are influenced by strategies developed in their native language when analysing sentences in their second language (see Durgunoglu & Hancin, 1992; Odlin, 1989, for extensive reviews). Results from several off-line studies performed in the framework of the "Competition model" (Bates & MacWhinney, 1982) indicate that this type of transfer does occur. For example, when asked to assign the role of subject to one of the nouns in NVN triplets presented in English, Japanese-dominant beginning bilinguals make use of animacy cues, as they do in Japanese, and much more so than do native monolingual speakers of English (Harrington, 1987). Increased use of the second language is, of course, influential, as shown by a cross-longitudinal study with English–Dutch and Dutch–English bilinguals (McDonald, 1987). The results of that study showed a clear picture of decreased use of first-language cues in favour of second-language cues with increased exposure to the second language (as measured by years of residency in the country of the second language). Nonetheless, an influence of the native tongue was still apparent, even in the most highly skilled group (over 15 years of residency). In like manner, two other studies performed in this framework revealed that even highly proficient bilinguals do not process sentences in their second language like native speakers do; they are considerably influenced by properties of their native language (Kilborn, 1989; Kilborn & Cooreman, 1987).

Transfer of native-language syntactic knowledge has been demonstrated in studies that compared the performances of bilinguals and of native speakers on grammaticality judgement tasks. Results show that when making grammaticality judgements to sentences in their second language, bilinguals make significantly more errors on sentences that respect the syntax of their first language than do monolingual control subjects (Mack, 1986; White, 1989). Structures that are highly specific to the native language are, however, apparently not considered grammatical in the second language (Birdsong, Johnson,

& McMinn, 1984, cited in Odlin, 1989, Section 6.2). Structural similarity between the native language and the second language is indeed a determining factor as concerns the degree of transfer of native-language structures and hence the difficulty of second-language interpretation (Flynn, 1989; Wekker, Kellerman, & Hermans, 1982, cited in Kellerman, 1989). However, as pointed out by Kellerman (1989), close examination of the types of errors made in both the production and analysis of sentences in the second language reveals that even in cases where two languages are structurally close, not all features of the native language will be transferred. Rather, it is the subject's *perceived* similarity of structures between the two languages that determines transfer.

The present study aimed at examining in finer detail the strategies that bilinguals engage upon when reading in their second language. Two on-line reading experiments were conducted, in which subjects' eye movements were recorded while they read single sentences. Experiment 1 examined second-language reading performance for sentence structures that were locally ambiguous. The primary aim was to investigate whether bilinguals, reading in their second language, would resolve these ambiguities differently from native readers of the language. A secondary aim was to examine readers' use of lexical information carried by the verb when resolving syntactic ambiguities. The structures used in Experiment 1 were in fact identical in our bilinguals' first and second languages. Hence, any difference in syntactic ambiguity resolution observed between bilinguals and native readers would be attributable to subject strategies, and not to an influence of the bilingual's maternal language. Experiment 2 also investigated the processing of ambiguous structures; however, unlike Experiment 1, the sentences were ambiguous in only one of our bilingual readers' languages. The ambiguity of these structures was linked to properties of the verb. Here, the question was whether lexical information from the native language, conveyed by the verb, would override that from the second language in cases where the two languages conflict, leading to the erroneous parsing of sentences. Experiment 2 thus examined a particular type of transfer from the native language, that of lexical constraints.

EXPERIMENT 1

The first experiment examined second-language performance in the face of syntactic ambiguity. To our knowledge, although syntactic ambiguity resolution has been the topic of numerous monolingual studies (see Altmann & Steedman, 1988; Frazier, 1989, 1990; Mitchell, 1994; MacDonald, Pearlmutter, & Seidenberg, 1994; for recent reviews), it has not been studied on-line in the second language.

We chose to examine the processing of sentences that contained temporarily ambiguous prepositional phrases (PP), as illustrated in Example 1.

1. *Brutus hit the gladiator with the shield with his bare hands.*

In this example, the prepositional phrase "with the shield" is ambiguous, as it can be attached either to the verb phrase (the shield was the instrument) or to the second noun phrase (the gladiator had the shield). How this particular syntactic ambiguity is resolved has been the object of considerable debate. On the one hand, there is evidence that VP

attachment of the PP is initially preferred over NP attachment (Clifton, Speer, & Abney, 1991; Rayner, Carlson, & Frazier, 1983), even in cases where NP attachment is pragmatically more acceptable (Rayner et al., 1983). These results fit well with a phrase-structure-driven parser, which relies on major syntactic category information coupled with principles of syntactic parsimony to perform the initial syntactic analysis of sentences (Frazier, 1987, 1990; Rayner et al., 1983). Indeed, on the basis of a simple phrase structure grammar, it can be shown that NP attachment is more costly, in terms of nodes in the tree structure, than is VP attachment. Nonetheless, other monolingual work has shown that non-syntactic factors can influence PP attachment. In one study, semantically biasing the sentence frame produced the opposite effect from that reported above—that is, processing times were shorter for NP than VP attachment of the PP (Taraban & McClelland, 1988). In another study, referential context (provided by a short paragraph) influenced PP attachment in subsequent test sentences such that either NP or VP attachment of the PP was preferred, in accordance with the context (Altmann & Steedman, 1988). It should be noted, however, that both of these studies recorded self-paced reading times, and the effects were obtained either after the word that actually determined PP attachment (Taraban & McClelland, 1988) or for the entire PP region, which contained two to three words (Altmann & Steedman, 1988). This is important, given that it has been suggested that the long reading times generally obtained with this measure may include not only initial syntactic processing, but re-analysis as well (Frazier, 1987, 1990; Mitchell, 1989). The argument that extra-syntactic information actually drives the parser would perhaps be stronger if supported by a more immediate on-line measure.

The ambiguity posed by PP attachment provides an interesting framework in which to study non-native processing. On a general level, it is possible to determine whether non-native readers will perform the same syntactic parse of this structure as native readers. At a more specific level, by manipulating the properties of the verb that precedes the ambiguous PP, we can examine whether non-native readers' processing strategies are sensitive to detailed lexical information. The materials we employed were of the type presented in Examples 2 and 3:

2a. *They accused the ambassador of espionage but nothing came of it.*
2b. *They accused the ambassador of Indonesia but nothing came of it.*

3a. *He rejected the manuscript on purpose because he hated its author.*
3b. *He rejected the manuscript on horses because he hated its author.*

In Version a of these sentences, the noun of the PP is congruent with VP attachment of the PP. In Version b, the noun of the PP is congruent with NP attachment. If initial syntactic analysis is made on the basis of major syntactic category information together with general syntactic principles (Clifton et al., 1991; Frazier, 1987, 1989, 1990; Rayner et al., 1983) then Version a should be easier than Version b for both Examples 2 and 3. Note, however, that Examples 2 and 3 differ with respect to the properties of the verb preceding the PP. In Example 2, the first verb is ditransitive and allows for two arguments following the verb. In Example 3, the first verb is monotransitive and allows for only one argument following the verb. This type of lexical information, associated with the verb, is important

in lexically (frame) driven models of parsing, because they assume that it influences initial syntactic analysis (Boland, 1993; Ford, Bresnan, & Kaplan, 1982; Shapiro, Nagel, & Levine, 1993; Trueswell, Tanenhaus, & Kello, 1993). In this framework, one can predict differences concerning the attachment of the PP as a function of the verb that precedes it. More precisely, VP attachment of the prepositional phrase may be preferred by the reader over NP attachment for ditransitive verbs only, because for this type of verb the reader should anticipate two arguments. In this case, Example 2a should be easier to parse than Example 2b, but Example 3a should not necessarily be easier, and in fact may initially be more difficult to analyse than Example 3b. These predictions can be tested both on-line, during the reading of complete sentences, as well as off-line, by testing subjects' completions of sentence beginnings that contain these verbs. Both approaches were adopted here.

The above predictions hold for native readers of the language. Concerning our non-native readers, it should first be underlined that the structure in question exists in both their native and their second language; moreover, the lexical constraints of the critical verbs were similar in the two languages. Given this, if when reading in their second language bilinguals rely on extra-syntactic cues—in the present case lexical information—then one would predict that the lexical information conveyed by the verb may be especially important to the non-native reader. In this case, one would predict ease of VP attachment following ditransitive verbs (Version a) and of NP attachment following monotransitive verbs (Version b), as with native performance. However, it is not immediately apparent that non-native readers will be able to extract specific lexical information rapidly enough for it to play a role in initial syntactic analysis. At the lexical level, it is well known that non-native readers identify words at a slower rate than do native readers, at least in the first few years of use of the second language (Favreau & Segalowitz, 1983; Frenck-Mestre, 1993). Furthermore, there is evidence at the sentential level that non-native readers do not integrate semantic and syntactic information as rapidly as do native speakers (Kilborn, 1993), and at a textual level that intermediate non-native readers are less sensitive to semantic and syntactic constraints than are native readers (Cziko, 1980).

If non-native readers are *not* influenced by lexical information during the initial parse of sentences in their second language, it remains to be demonstrated that, for the structure in question, they will show a general "VP attachment preference" of the PP. As outlined above, advocates of a phrase-structure model of parsing claim the relative ease of VP compared to NP attachment to be due to the application of the principle of Minimal Attachment, which chooses the structure involving the lesser number of nodes. It can be noted that without this overriding principle, one would actually expect NP attachment of the PP to be easier, due to the principle of "right association" (Kimball, 1973) or of "late closure" (Frazier & Fodor, 1978), which asserts that low attachment should be preferred. It is possible that, for non-native readers, the parser is not as efficient as it might be, in which case one might well observe a preference for NP attachment of the PP, irrespective of the type of verb preceding it. This "low-attachment" strategy could also arise due to heuristic processing in the second language, given that in this particular structure (NP1, VP, NP2, PP), low attachment amounts to attaching the PP to the most recently processed constituent, the second NP.

In summary, Experiment 1 allowed us, first, to examine how bilinguals resolve syntactic ambiguities in their second language, for structures that were identical in their

native and second languages. If bilinguals behave as native readers and if ambiguities of the nature tested here are influenced by lexical information carried by the verb, we predict VP attachment to be easier than NP attachment only for sentences in which the PP was preceded by a ditransitive verb. However, if bilinguals do not benefit from lexical information but adopt a general strategy of attaching incoming information "low"—that is, to the currently processed constituent—then they should show a general preference for NP over VP attachment of the PP.

We chose to record eye movements as a measurement of processing. This measure is widely regarded, in the monolingual literature, as a sensitive early measure of syntactic processing (cf. Rayner et al., 1989, for a review). In contrast, bilingual studies on reading have predominantly used off-line measures, and to our knowledge very few studies have investigated bilinguals' patterns of eye movements when reading in their second language. Hence, the information provided by the present experiment should help to fill a void in this area of research.

Pilot Study

Prior to the experiment proper, we ran a pilot study, in order to obtain native readers' attachment preferences for the sentences to be used in Experiment 1. In the pilot study, 56 French undergraduate psychology students were asked to provide completions to 70 sentence beginnings (in French) presented in a single list, which began with four complete sentences. Of the 70 sentence beginnings, 24 were in fact the beginnings of sentences to be used in Experiment 1, and 46 were fillers. The experimental sentence beginnings were all of the type shown in Examples 2 and 3: *Ils accusent la femme de* [They accuse the woman of], versus "*Elle regarde la vendeuse de*" [literally: She looks at the saleswoman of]. Twelve of the experimental sentence beginnings contained ditransitive verbs (e.g. inform, accuse, etc.), and 12 contained monotransitive verbs (e.g. look, clean, etc.). All of the experimental beginnings ended with the preposition *de* [of] or *du* [of the], and all could, in principle, be completed with a noun that required the PP to be attached to the VP or with a noun that required the PP to be attached to the preceding NP. The 46 filler beginnings contained verbs of various types and ended either with a preposition (*avec*, *sans*, *en*, *de*) or with the verb itself. The 70 sentence beginnings were presented in a different random order for each subject, in a three-page booklet, and subjects were asked to complete the sentences with the first word(s) that came to mind.

The results of the pilot study were quite clear-cut. For sentence beginnings that contained verbs that generally took two complements, subjects gave 76% of completions that implied VP attachment of the PP, and 20% of completions that implied NP attachment. That is, when given (in French) the beginning *They accused the gangsters of*, native readers were much more likely to complete the sentence with *robbery* than with *Marseille*. In contrast, for sentence beginnings that contained monotransitive verbs, 82% of subjects' completions implied NP attachment of the PP, and only 15% implied VP attachment. For example, given the beginning, *Elle regarde la vendeuse de*, subjects answered with a noun such as *robes* [She looks at the saleslady in the clothes department] much

more often than with a word like *travers* [She looks at the saleslady in anger]. Analyses of variance (ANOVAs) of the total number of VP and NP attachments for each of the two verb types confirmed the significance of the interaction described above, $F_1(1, 55) = 744.24$, $p < .001$, $F_2(1, 22) = 54.43$, $p < .001$. Inspection of the means revealed, nonetheless, that two verbs (one in each category) incited completions that were either ambiguous or opposite to those of the other verbs in their category. Each of these was replaced with another verb (sentence) for Experiment 1. These materials were then presented to native speakers and to bilinguals in the eye-movement experiment described here.

Method

Subjects

A total of 32 men and women, all with uncorrected vision, voluntarily participated in the experiment, which lasted roughly 30 minutes; 16 subjects were American college students residing in France and studying at a French university (mean = 9 mo.). All had learned French in a scholastic environment and had studied the language for at least 5 years (at secondary and college level) prior to living in France. All were fluent enough in this language to be successful at university courses conducted in French. For all of the bilinguals, the native language was English, and all of the bilinguals had been raised in a monolingual environment; 16 subjects were French college students who were native speakers of French and who considered themselves monolingual.

Materials

Twenty-four sentence pairs were used. In 12 of the pairs, the first verb accepted two complements (e.g. *accuse*); in the other 12, the first verb accepted one complement (e.g *look*). These two categories of verbs were taken from Bescherel (1966). For the category of ditransitive (2-complement) verbs, all could be employed with a single complement, but all were listed as being commonly used with two complements, the second of which was always introduced by the preposition *de* [of]. The category of monotransitive (1-complement) verbs allowed for only one argument following the verb, such that any prepositional phrase following the NP2 could not be an argument of the verb. For this type of monotransitive verb, when the PP is attached to the VP, the PP is an adjunct and not an argument of the verb. The lexical constraints of the verbs that we used were identical in English and in French. This was done to avoid possible interference from the native language of our bilingual subjects. All sentences began in the same manner: personal pronoun, verb, direct object NP, prepositional phrase. For each of the 24 sentence pairs, the PP modified the preceding VP in one version of the sentence, and the object NP in the other. Attachment of the PP was determined only by the noun of this constituent. The prepostion itself was always either *de* [of] or *du* [of the]. The two sentences of a pair were otherwise identical. The two nouns that distinguished sentence pairs were matched for length and for frequency. A subject saw only one version of a sentence, although each sentence (verb type) was seen with each type of attachment of the PP. Subjects thus saw only one of two lists, each of which contained 24 experimental sentences (six of each type) mixed with 52 fillers of various structures. All 24 experimental sentences were logical; 14 of the fillers were logical and 38 were illogical. Illogical sentences were of the nature: *It was a shame that the old man had drowned when just a boy.* Subjects were told that their task was to determine which sentences were logical, and they were given this example at the outset of the experiment.

Apparatus and Procedure

Subjects' eye movements were recorded using an infrared limbus-tracking device mounted on adjustable eyeglass frames. Horizontal signals from the right eye were sampled every 5 msec using a 12-bit A/D device interfaced to an Opus 386 computer. Subjects viewed the display binocularly while seated 60 cm from the screen, with their head restrained with a bite-bar and adjustable head and chin rests. The apparatus was calibrated every four sentences using an array of five single digits across the display screen. Overall accuracy of the system was approximately ± 0.5 characters. Sentences were presented individually on a high-resolution display monitor. They were displayed in a single line in normal upper and lower case. Sentence presentation was contingent on the subject's fixating a fixation point located at the far left of the screen. Subjects read the sentences silently and indicated whether or not they were logical by pressing one of two buttons marked *oui* and *non* located on a response box under the right and left hand.

Data Analysis

For analysis purposes, sentences were divided into 5 regions: (1) the initial area up to the noun of the PP, (2) the noun of the PP (N of PP), (3) the following word (N + 1), (4) the word thereafter (N + 2), and (5) the final region up to the penultimate word of the sentence:

Elle protège les enfants du/*danger*/mais/ils/ne s'en rendent/pas compte.
Elle protège les enfants du/*village*/mais/ils/ne s'en rendent/pas compte.

For a few sentences, the words following the noun of the prepositional phrase were very short (2 letters). In these cases, region N + 1 and/or N + 2 was extended beyond a single word, to comprise 5 character spaces (blanks included). This reduced the probability that a region would be skipped, but it could not differentially affect processing time, given that two sentences of a pair were identical, with the exception of the noun of the PP. If a region was skipped, this was treated as a missing case, and the mean was taken from the remaining cases.

The results obtained for three regions of sentences—Noun of the PP, N + 1, and N + 2—are the areas of theoretical interest to the present study. Note, however, that preliminary analyses showed no reliable differences in processing for the initial and final regions of sentences as a function of experimental factors. The data are reported in terms of first pass reading times, second pass reading times, and the number of interzone regressions launched during the first pass through the sentence.

Results

First Pass Reading Times

The mean first pass reading times are summarized in Table 1. First pass reading times were defined as all left-to-right fixations within a region that had not been previously read, plus all within-zone regressions. When the eye left the region, due to either a forward motion or a regressive saccade, first pass reading was considered complete. Both first pass gaze durations (i.e. the sum of all first pass fixations within a region) and first fixation durations are reported. The data for each of the three sentence regions—Noun of PP, N + 1 and N + 2—were subjected to independent analyses, as it is of crucial importance to determine whether effects were obtained early in processing, at the initial point of disambiguation, or only later.

TABLE 1
Mean First Pass Measures for Each of the Three Sentence Regions[a] as a Function of Subject Group, Verb, and PP Attachment

	Monolinguals in French			*Bilinguals in L2 (French)*		
	Noun of PP	*Noun + 1*	*Noun + 2*	*Noun of PP*	*Noun + 1*	*Noun + 2*
Ditransitive						
VP Attachment						
Means	380 (290) 6	319 (261) 5	387 (258) 10	366 (273) 17	325 (256) 4	350 (250) 10
SD	68 (32)	45 (45)	76 (40)	78 (62)	94 (50)	101 (44)
NP Attachment						
Means	432 (292) 10	320 (246) 6	334 (253) 13	416 (300) 9	352 (262) 3	427 (257) 6
SD	73 (33)	60 (37)	84 (39)	99 (50)	81 (69)	66 (50)
Monotransitive						
VP Attachment						
Means	442 (291) 19	331 (275) 11	373 (250) 15	463 (330) 18	415 (281) 11	379 (258) 15
SD	79 (65)	99 (33)	78 (35)	92 (52)	91 (34)	96 (65)
NP Attachment						
Means	411 (283) 10	287 (254) 8	395 (261) 10	397 (286) 9	335 (275) 11	439 (267) 7
SD	50 (66)	74 (45)	94 (56)	74 (43)	78 (45)	93 (62)

[a] N + 1 and N + 2 = first and second word following the noun of the PP.

Note: Gaze durations are presented outside of and first fixation durations within parentheses, both in msec, followed by first pass interzone regressions (total = 243).

At the noun of the PP, the analysis of first pass gaze durations revealed an effect of verb, significant by subjects only, $F_1(1, 28) = 4.49$, $p < .04$; $F_2 < 1$, which was qualified by the interaction with attachment, $F_1(1, 28) = 8.37$, $p < .01$; $F_2(1, 20) = 7.86$, $p < .01$.[1] Tests of simple effects showed that gaze durations were longer for NP than VP attachment in the case of ditransitive verbs (e.g. *accuse*), $F_1(1, 28) = 4.99$, $p < .03$; $F_2(1, 10) = 3.66$, $p < .08$, and for VP than NP attachment in the case of monotransitive verbs (e.g. *look*), $F_1(1, 28) = 5.79$, $p < .02$; $F_2(1, 10) = 4.21$, $p < .07$, as can be seen in the left panel of Figure 1. This interaction replicates the findings obtained off-line for subjects' sentence completion preferences for each of the two verb types. Moreover, this interaction was not qualified by native language, F_1 and $F_2 < 1$.

At the region N + 1 (i.e. the word immediately following the noun of the PP), the analysis of gaze durations revealed a significant Verb $\times$ Attachment interaction, $F_1(1, 28) = 8.37$, $p < .01$; $F_2(1, 20) = 7.86$, $p < .01$, which was not qualified by native language, $F_1(1, 28) = 1.89$, n.s.; $F_2 < 1$. Tests of simple effects showed that for sentences containing monotransitive verbs (e.g. *look*), gaze durations were longer following VP than NP attachment, $F_1(1, 28) = 7.94$, $p < .01$; $F_2(1, 10) = 3.61$, $p < .08$, whereas gaze durations did not differ significantly for the two types of attachment following ditransitive verbs, F_1 and $F_2 < 1$. This interaction can be seen in the right panel of Figure 1. No other effects approached significance.

Finally, at the region N + 2, i.e. two words downstream from the critical noun, the Verb $\times$ Attachment interaction was no longer significant, $F_1 < 1$; $F_2(1. 20) = 1.53$, n.s., nor was it influenced by native language, F_1 and $F_2 < 1$.

A finer-grained analysis of these results is provided by the analysis of first fixation durations. At the noun of the PP, the Verb $\times$ Attachment interaction was significant, $F_1(1, 28) = 8.36$, $p < .01$; $F_2(1, 20) = 6.78$, $p < .02$.[2] Unlike the results for gaze durations, however, the interaction was qualified, in the subject analysis, by native language, $F_1(1, 28) = 4.72$, $p < .04$; $F_2(1, 20) = 2.34$, n.s. Independent analyses were run on the data for the two subject groups. For native readers, no effects were significant. For the group of bilinguals, the Verb $\times$ Attachment interaction was significant, $F_1(1, 14) = 8.02$,

[1] As pointed out by one reviewer, although there was an overall length match for the two nouns in a sentence pair, there were a few cases where the two nouns of a pair (i.e. one implying NP attachment and the other VP attachment of the PP) differed by more than 1 character. To ensure that our effects were not due to this artefact, we ran an analysis of covariance, with length as a covariate, on the item means. The results of this analysis revealed, as above, a significant Verb $\times$ Attachment interaction, $F_2(1, 19) = 7.47$, $p < .01$. Tests of simple effects revealed, as above, that gaze durations tended to be slower for NP than VP attachment following monotransitive verbs, $F_2(1, 9) = 4.67$, $p < .056$, and for VP than NP attachment following ditransitive verbs, $F_2(1, 9) = 3.78$, $p < .08$.

[2] As with the data for gaze durations, an analysis of covariance, with length as a covariate, was performed on the item means for first pass fixations at the noun of the PP. This analysis revealed a significant Verb $\times$ Attachment interaction, $F_2(1, 19) = 6.44$, $p < .02$, which was qualified by native language, $F_2(1, 19) = 8.99$, $p < .01$. An analysis of covariance performed on the item means for bilinguals revealed, as above, a significant Verb $\times$ Attachment interaction, $F_2(1, 19) = 5.76$, $p < .03$, and tests of simple effects confirmed, as above, that first fixation durations were longer for VP than NP attachment following monotransitive verbs, $F_2(1, 9) = 7.14$, $p < .03$, whereas they did not vary significantly as a function of type of attachment following ditransitive verbs ($F_2 < 1$).

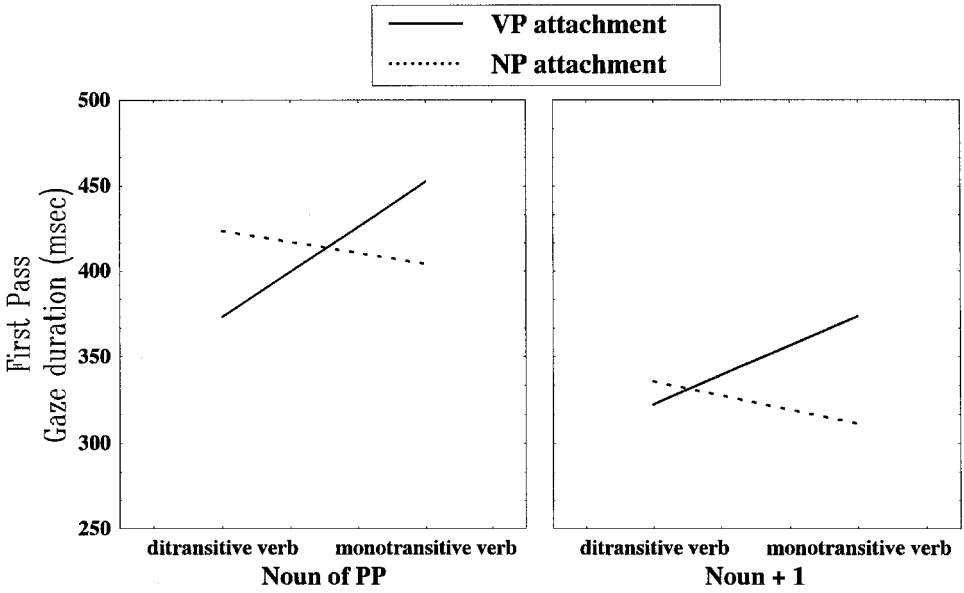

FIG. 1. Mean first pass gaze durations, for both native and non-native speakers, at the noun of the prepositional phrase and at the word immediately following the noun of the PP, as a function of the verb preceding the noun, and the type of attachment of the PP.

$p < .01$; $F_2(1, 20) = 6.07$, $p < .02$, and tests of simple effects showed that first fixation durations were noticeably higher for VP than NP attachment following monotransitive verbs, $F_1(1, 14) = 9.94$, $p < .01$; $F_2(1, 10) = 7.93$, $p < .02$, but did not differ significantly between the two types of PP attachment following ditransitive verbs, $F_1(1, 14) = 3.82$, $p < .07$; $F_2(1, 10) = 1.05$, n.s. These effects are visible in Table 1.

The independent analyses of first fixation durations at the regions N + 1 and N + 2 did not reveal any significant effects.

First Pass Interzone Regressions

Analyses were performed on the total number of first pass regressive saccades that subjects launched from the noun of the PP, the N + 1, and the N + 2 regions. These totals are given for each region as a function of verb, of PP attachment and of native language, in Table 1. Given the small number of regressions, independent analyses of the three sentence regions did not reveal significant effects. Note, however, that the global analysis of all three regions did not show any interactions with the factor Region.

The global analysis revealed significant effects of verb, $F_1(1, 28) = 15.06$, $p < .001$; $F_2(1, 20) = 8.59$, $p < .01$, and of attachment, $F_1(1, 28) = 14.60$, $p < .001$; $F_2(1, 20) = 6.75$, $p < .02$, as well as a significant interaction betwen the two in the subject analysis, $F_1(1, 28) = 5.27$, $p < .03$; $F_2(1, 20) = 3.73$, $p < .07$. More interzone regressions occurred for VP than for NP attachment in the case of monotransitive verbs, but there was no significant difference between VP and NP attachment in the case of ditransitive verbs (see Table 1), as confirmed by a Newman–Keuls analysis. The effect of attachment was also

qualified by native language, significantly so in the subject analysis, $F_1(1, 28) = 4.23$, $p < .05$; $F_2(1, 20) = 2.89$, $p < .10$. Bilinguals made more regressions following VP than NP attachment of the PP, whereas native speakers regressed in like manner following the two types of attachment, as confirmed by a Newman–Keuls analysis. The higher-order Verb $\times$ Attachment $\times$ Native Language interaction did not attain significance, $F_1(1, 28) = 2.76$, $p < .10$; $F_2(1, 20) = 2.89$, $p < .10$, despite apparent differences in means. No other effects were significant.

Second Pass Reading Times

Mean second pass reading times are given in Table 2, as a function of region, verb, attachment, and native language of subjects. Second pass reading times include all fixations not included in the first pass analysis and often comprise more than one re-reading of the sentence. For this reason, the immediacy of effects is not relevant. Consequently, analyses were performed on the data for all three regions rather than for each region independently.

The effect of native language was significant, $F_1(1, 28) = 8.76$, $p < .01$; $F_2(1, 22) = 26.79$, $p < .001$, revealing longer re-reading times for bilinguals than for native speakers. Neither the effect of verb, $F_1 < 1$; $F_2 < 1$, nor that of attachment attained significance, $F_1(1, 28) = 2.03$, n.s.; $F_2 < 1$; however, the Verb $\times$ Attachment interaction was significant, $F_1(1, 28) = 3.96$, $p < .056$; $F_2(1, 22) = 4.64$, $p < 0.04$. Subjects spent more time re-reading monotransitive verb sentences following VP than NP attachment of the PP (496 vs. 395 msec, respectively, $F_1(1, 28) = 7.78$, $p < .01$; $F_2(1, 10) = 4.27$, $p < .06$, but they did not show a notable difference between the two structures for sentences containing ditransitive verbs (402 vs. 426 msec for VP and NP attachment, respectively, F_1 and $F_2 < 1$). No other effects were significant.

Discussion

The experiment addressed two questions: first, would non-native readers resolve local syntactic ambiguity differently from native readers; second, would ambiguity resolution be influenced by lexical information. The data provide some support for the first of these questions, but strong evidence for the latter.

The combined results for native readers and non-native readers showed a localized effect of lexical information on syntactic ambiguity resolution. Subjects preferred to attach prepositional phrases high, to the verb phrase, or low, to the noun phrase, in accordance with the type of verb preceding the PP. It can be noted that this preference is in line with that found for sentence completions in the pilot study, for different subjects (see also Taraban & McClelland, 1988; but Shapiro et al., 1993). The effect of lexical information on on-line syntactic processing was apparent at the critical region of the sentence—that is, where PP attachment was determined—as well as one word downstream from the critical region. Thus, it can be said that lexical information rapidly influenced syntactic ambiguity resolution. It is also important to note that this localized effect of lexical information was not dependent upon the type of reader.

TABLE 2

Mean Second Pass Reading Times[a] for Each of the Three Sentence Regions as a Function of Subject Group, Verb, and PP Attachment

	Monolinguals in French						*Bilinguals in L2 (French)*					
	Ditransitive			*Monotransitive*			*Ditransitive*			*Monotransitive*		
	N	*N + 1*	*N + 2*	*N*	*N + 1*	*N + 2*	*N*	*N + 1*	*N + 2*	*N*	*N + 1*	*N + 2*
VP Attachment												
Means	247	281	514	308	199	384	656	324	547	467	428	587
SD	155	237	303	157	229	252	219	197	373	223	198	324
NP Attachment												
Means	326	269	344	530	301	450	458	363	654	576	488	628
SD	298	265	192	234	159	193	332	287	233	239	241	212

[a] In msec.

These results lend support to a lexically driven model of parsing. According to this model, the subcategorization and/or thematic information specified by a verb can be used immediately, such that when the verb precedes its arguments, the reader can anticipate the type of argument s/he is likely to encounter (Boland, 1993; Shapiro et al., 1993; Trueswell et al., 1993). It could be argued, nonetheless, that our results do not rule out a phrase-structure model, such as that put forward by Frazier and colleagues (Clifton et al., 1991; Frazier, 1987, 1989, 1990; Rayner et al., 1983). In line with the latter model, lexical and/or thematic information may have time to come into play following the initiation of syntactic analysis based on major category information. Given the structure that we used, it is possible that subcategorization information became available *following* the reading of the verb, during the processing of the object NP, and exerted its influence when the attachment of the PP became necessary. Note that to be consistent with this argument one must either claim that, in the case of NP attachment of the PP, the initial VP attachment is rapidly revised on the basis of thematic information (cf. Frazier, 1990), or that initial PP attachment decisions can be driven by thematic information, although this information is only available after the initial processing of the verb. Given that we did not find VP attachment to be faster overall, as should be the case if subjects were systematically revising their analysis when faced with NP attachment, it would appear that only the latter argument can explain our data.

It is worth noting that, for the group of native readers, the effect of lexical information was found for the total first pass reading time for a region. However, it did not appear to influence first fixation durations. There is some question, indeed, as to which measure of eye movement behaviour should be taken as being indicative of initial parsing decisions. It has been suggested that first fixation durations are the best evidence of these early decisions (Ferreira & Henderson, 1990). However, the processing of a word is not systematically completed within a single fixation and can in fact "spill over" onto subsequent fixations (Rayner & Pollatsek, 1987). Rayner and colleagues (Rayner, Sereno, Morris, Schmauder, & Clifton, 1989) have suggested that a range of measures—first fixation duration, gaze duration, second pass reading times, probability of making a regression out of a region—should be taken into account when determining whether a given effect is the product of initial analysis or, rather, reflects re-analysis processes. In our study, all of these measures but one showed an effect of subcategorization information provided by the verb on syntactic ambiguity resolution. It seems likely that the effect of this factor was not restricted to re-analysis, but that it affected initial parsing decisions.

The region that determined PP attachment contained a single word (e.g. Elle protège les enfants du *danger/village*). Given that, for native speakers, PP attachment was influenced by the preceding verb in the analysis of gaze durations but not first fixations, it is possible that the processing of this one-word region was also influenced by factors other than the lexical information provided by the verb. Indeed, although word length and number of syllables at the PP region were controlled across conditions, they were not perfectly matched, and this could have affected processing times. Note, however, that there was no systematic bias of word or syllable length, nor can the cross-over interaction we obtained between verb type and PP attachment be explained by this type of bias. Moreover, both the results of the covariate analysis, taking length of the PP into account, and the fact that differences in first fixations were obtained at the PP region in the

bilingual group suggest that our effects were not due solely to slight differences in the length of the PP region.

Our data do not provide evidence that non-native readers systematically engage in processing strategies that are qualitatively different from those of native readers. However there were signs that non-native readers experienced greater difficulty with high (VP) attachment of prepositional phrases than did native readers. This was visible in the non-native readers' patterns both of regressive saccades and of first fixations. Non-native readers tended to regress more often following high (VP) than low (NP) attachment of the PP, irrespective of the preceding verb. Concerning first fixations, it should perhaps be recalled that this measure was not sensitive to lexical or syntactic factors in the group of native readers. It was indicative of processing difficulty in the non-native group, however, and specifically for VP attachment. More precisely, for sentences containing verbs that generally took two complements (i.e. suspect, convict, etc.), our bilingual readers did not show a difference in first fixation durations for VP and NP attachment of the subsequent PP. However, when the preceding verb was one that generally took only one complement (i.e. look, know, etc.), these subjects experienced momentary difficulty with VP attachment compared to NP attachment. In other words, when the preceding verb provided information that allowed the reader to expect a modification of the verb phrase, our bilinguals did not experience difficulty with VP attachment. They did experience difficulty with VP attachment, however, in the absence of this information. The latter effect was not so much specific to the group of non-native readers as more immediate. It was in fact true of both native and non-native readers when first pass gaze durations are considered. The most parsimonious account of these results thus appears to be that although non-native readers may have a "low" or "local" attachment strategy, this strategy can be influenced by lexical information provided by the verb, in the same manner that native speakers are sensitive to this information.

Native and non-native performance differed as concerns second pass reading times. Bilinguals globally spent more time re-reading sentences than did native speakers. Given that this effect of language did not otherwise affect the pattern of second pass reading times, and that it was not globally apparent in the analyses of first pass reading times, it is most probably due to our bilingual readers' desire to perform in the second language. Where the native reader was content with perhaps a single reading of the sentence, the bilingual was more prone to re-read the sentence to be sure s/he had understood it properly.

In the next experiment, we aimed to extend the findings of Experiment 1. Recall that in the present experiment we intentionally employed structures that were identical in the bilinguals' two languages, to study parsing in conditions where the native language could not produce interference. In Experiment 2 we examined bilinguals' performance in the second language under conditions where the native language provided information that was in conflict with that provided by the second language.

EXPERIMENT 2

In Experiment 2, we again examined how bilinguals parse sentences in their native and in their second language, but now we manipulated the degree of overlap of information in the two languages. The objective was to examine the syntactic parsing performed by

bilinguals in their two languages, in cases where the lexical constraints of verbs were at odds with each other in the first and second language. In this manner, we wished to determine whether lexical information from the bilinguals' first language would, perhaps at least momentarily, override lexical information from the second language.

As outlined in the general introduction, various studies have revealed transfer of native-language grammatical knowledge and/or processing strategies to the second language, even in cases where inappropriate (Harrington, 1987; Kilborn, 1989; Kilborn & Cooreman, 1987; Koda, 1993; Mack, 1986; McDonald, 1987; White, 1989). Furthermore, at the lexical level, it has been shown that bilinguals are generally incapable of selectively attending to a single lexicon, and, conversely, that both lexicons are active even in monolingual tasks (Beauvillain & Grainger, 1987; Cristoffanini, Kirsner, & Milech, 1986; Grainger & Dijkstra, 1992; but see Gerard & Scarborough, 1989). Thus, the information associated with lexical entries in the native language may well become active when bilinguals read sentences in the second language. Moreover, the lexical information from the native language may become available more quickly than that from the second language, depending upon the respective frequencies of the words in the two languages (Beauvillain & Grainger, 1987) and/or the level of experience of the bilingual (Frenck-Mestre, 1993). Given the above, the parser may, at least momentarily, erroneously adhere to rules from the native language when the native language and second language present conflicting lexical information.

We presented our bilingual readers with sentences that were structurally ambiguous in only one of their languages:

4. Every time the dog obeyed the pretty little girl showed her approval.
   Chaque fois que le chien obéissait la jolie petite fille montrait sa joie.

5. Every time the dog barked the pretty little girl showed her approval.
   Chaque fois que le chien aboyait la jolie petite fille montrait sa joie.

Example 4 is ambiguous in English up to the main verb, given the nature of the subordinate verb "obey", which can be used either transitively or intransitively. This is not the case in Example 5, in which the subordinate verb "bark" is obligatorily intransitive. In French, however, Examples 4 and 5 do not differ from each other, as the subordinate verb (*obéir* [obey], and *aboyer* [bark]) is obligatorily intransitive in both.

In line with previous monolingual results, we can expect that native readers of English will experience difficulty at the main verb of English sentences such as Example 4 (Frazier & Rayner, 1982; Kennedy & Murray, 1984; Rayner et al., 1983). This is so because in Example 4, where the subordinate verb is optionally transitive, the reader should assign the role of direct object to the post-verbal NP "the girl" and be obliged to revise this analysis upon reading the main verb. In Example 5, however, the reader should be in no doubt as to the structure of the sentence when s/he reaches the matrix verb, because the post-verbal NP will have been rejected as a possible direct object of the subordinate verb given the strict intransitive nature of this verb (we shall remain non-committal, here, as to whether or not the direct object analysis of the post-verbal NP is *immediately* blocked by

subcategorization information: cf. Ferreira & Henderson, 1990; Frazier, 1987, 1989; Frenck-Mestre & Pynte, 1995; Holmes, 1987; Kennedy, Murray, Jennings, & Reid, 1989; Mitchell, 1989; Osterhout & Swinney, 1989; Trueswell, Tanenhaus, & Kello, 1993). In contrast to the predictions for these sentences in English, one would not expect a difference in processing difficulty between Examples 4 and 5 in French. There is no reason that a native reader of French should experience greater difficulty with one or the other of these sentences, given that they are virtually identical (concerning structure and lexical constraints) in this language.

Consider, now, the syntactic analysis that English-dominant *bilingual* readers might perform on Examples 4 and 5, presented in French. If, as a general rule, bilinguals correctly apply the lexical constraints of the language they are currently reading, without interference from the non-pertinent language, one would not predict English-dominant bilinguals to demonstrate differences in processing difficulty for the two sentence types in French. However, if bilinguals initially analyse sentences in the second language in accordance with the lexical constraints of their native language, then we would expect English-dominant bilinguals to experience difficulty with Example 4 compared to 5, in French as well as in English. For French-dominant bilinguals, similar predictions can be made. They should parse Examples 4 and 5 without difficulty in French. In English, they should experience difficulty with Example 4 compared to 5 if they obey lexical constraints from the second language, but not if they import lexical constraints from their native language.

Method

Subjects

Thirty-two adult bilinguals with uncorrected vision participated in the experiment, which lasted approximately 40 minutes. Subjects were not paid for their participation. Of the subjects, 16 were American students residing in France and studying at a French university (mean of 9 months). All had studied French formally in the United States for at least 5 years before living in France. The other 16 subjects were native French university students studying to become English instructors (5th year of university studies in English), having recently lived for 9 to 12 months in the U.S. or the U.K. None of the subjects had participated in Experiment 1, and all were naive with regard to the purpose of the study.

Materials and Design

Sixteen pairs of experimental sentences were constructed. All experimental sentences contained a main clause preceded by a subordinate clause. The two sentences in a pair were identical except for the verb in the subordinate clause. The subordinate verbs were of two types: either intransitive in both English and French ("compatible"), or optionally transitive in English and intransitive in French ("incompatible") (Bescherel, 1966; Webster, 1983). All of the verbs had a single unambiguous equivalent in the other language. All of the optionally transitive verbs were employed intransitively in the experimental sentences. The two sets of verbs were matched as closely as possible for length and frequency, but the optionally transitive verbs were in fact slightly more frequent than were the intransitive verbs (*Trésor de la langue française*, 1971; Kucera & Francis, 1967). The 16 experimental

sentences were distributed across 4 lists, such that each sentence was seen in both languages and with both verbs, but no more than one version of a sentence appeared in a list. Languages were blocked. Subjects thus read 8 experimental sentences, 4 with each verb type, in each language. The experimental sentences were embedded in a list of 32 filler sentences of varying syntactic structures and comparable in length to the experimental sentences. Of the fillers, 4 were used for initial practice on the task. The remaining fillers, plus the experimental sentences of each list, were presented in a different random order for each subject; 12 of the fillers and all 8 experimental sentences in a list called for a positive response in a secondary task (i.e. whether or not the sentence made sense), and 20 fillers called for a negative response.

Apparatus and Procedure

These were identical to those of Experiment 1.

Data Analysis

For purposes of analysis, the sentences were divided into six regions: (1) the initial region up to the subordinate verb, (2) the subordinate verb, (3) the first two words of the following NP, (4) the last two words of the NP, (5) the verb of the main clause, and (6) the final region up to the penultimate word of the sentence:

2. Every time the dog/(obeyed/barked)/the pretty/little girl/showed/her/approval.
   Chaque fois que le chien/(obéissait/aboyait)/la jolie/petite fille/montrait/sa/joie.
   1 2 3 4 5 6

Reported are the results obtained for three regions of the sentences: (1) subordinate verb (Region 2), (2) beginning of NP (Region 3), and (3) main verb (Region 5). The first of these regions is of critical interest, as it is here that the bilingual's two languages differed concerning lexical constraints. The initial area of the NP is important because it is here that processing difficulty (or ease) associated with subcategorization information provided by the verb has been previously reported (Adams, Clifton, & Mitchell, 1994; Mitchell, 1987, 1989; Osterhout & Holcomb, 1992; Osterhout, Holcomb, & Swinney, 1994). Finally, the region of the main verb is important, given that it is here that disambiguating information is provided and where previous authors have found differences linked to processing difficulty (Frazier & Rayner, 1982; Kennedy & Murray, 1984; Mitchell & Holmes, 1985; Rayner et al., 1983). It is important to note that preliminary analyses of reading times did not show reliable processing differences for the initial and final regions of the two sentence types as a function of experimental factors.

The data were analysed in terms of first pass reading times per region (first fixation durations and gaze durations), second pass reading times, and the number of regressive saccades launched from a region to a prior one during the first reading of the sentence. First pass reading times were defined, as in Experiment 1, as all left-to-right fixations within a region that had not been previously read, plus all within-zone regressions. Second pass reading times included all fixations not included in the first pass analysis; hence they often included several re-readings of the sentence. Note that we did not measure reading time in terms of average fixation per character or per word, given that the sentences were identical with the exception of the verb in the subordinate clause, and the two sets of verbs were matched for length and, as closely as possible, for frequency.

Results

First Pass Reading Times: English Sentences

The mean first pass gaze durations and first fixation durations obtained for English sentences are summarized in Table 3. Independent ANOVAs were performed on the data obtained for the subordinate verb, the beginning of the NP, and the matrix verb.

At the subordinate verb, the effect of native language, $F_1(1, 24) = 7.52$, $p < .01$; $F_2(1, 12) = 25.39$, $p < .001$ and of sentence (verb) type, $F_1(1, 24) = 29.83$; $F_2(1, 12) = 6.19$, $p < .03$, were significant, as was their interaction, at least by subjects, $F_1(1, 24) = 11.16$, $p < .01$; $F_2(1, 12) = 3.45$, $p < .09$. Native readers (i.e. English-dominant bilinguals) did not show a significant difference in performance between optionally transitive and intransitive verbs (340 vs. 308 msec, respectively, $F_1(1, 12) = 2.09$, n.s.; $F_2 < 1$), whereas non-native readers (i.e. French-dominant bilinguals) demonstrated reliably slower reading times for optionally transitive than for intransitive verbs (482 vs. 348 msec, respectively, $F_1(1, 12) = 42.21$, $p < .001$; $F_2(1, 12) = 7.01$, $p < .02$).[3] This result demonstrates an influence of the native language on second-language processing. The French-dominant bilinguals experienced greater difficulty with English verbs that behaved differently from their French translations than with verbs that had the same constraints in the two languages. Indeed, whereas the intransitive verbs were intransitive in both English and French, the optionally transitive verbs were so in English but were strictly intransitive in French. The above interaction effect was apparent for gaze durations—that is, the total time subjects spent reading the verb during the first pass—but it did not affect the duration of first fixations. The analysis of first fixation durations revealed only an effect of native language, $F_1(1, 24) = 8.87$, $p < .01$; $F_2(1, 12) = 17.59$, $p < .001$, due to shorter first fixations in the group of native readers (see Table 3).

At the beginning of the NP region, the analysis of gaze durations revealed a trend towards a Sentence Type $\times$ Native Language interaction in the subject analysis, $F_1(1, 24) = 3.99$, $p < .057$; $F_2(1, 12) = 2.84$, n.s. In line with previous monolingual results (Adams et al., 1994; Mitchell, 1987), native readers showed a tendency for longer reading times of the NP following intransitive than following optionally transitive verbs (433 vs. 389 msec, respectively; $F_1(1, 12) = 3.59$, $p < .08$; $F_2(1, 12) = 3.35$, $p < .09$), whereas reading times did not differ significantly following the two verb types in the group of non-native speakers (468 vs. 412 msec, respectively; $F_1(1, 12) = 1.18$, n.s.; $F_2(1, 12) = 1.30$, n.s.). This effect will not be discussed further, given the weak trend (see, however, Adams et al., 1994; Mitchell, 1987, for discussions). The analysis of first fixation durations revealed no significant effects.

Finally, at the matrix verb, the analysis of gaze durations revealed only a non-significant trend for the effect of sentence type, $F_1(1, 24) = 2.45$, n.s.; $F_2(1, 12) = 1.35$, n.s. Mean reading times were in the predicted direction, with longer processing of the matrix verb in

[3] Although verbs were matched for length across the two conditions, they were not identical in length for a given pair. To ensure that our effects were not due to this artefact, a covariate analysis, with length as a covariate, was run on the item means obtained in the group of French subjects. The results of this analysis revealed a significant effect of verb, $F_2(1, 11) = 6.42$, $p < .03$.

TABLE 3
Means and Standard Deviations For First Pass Gaze Durations, First Fixation Durations, Second Pass Reading Times, and Number of First Pass Interzone Regressions Launched from a Region, for Experiment 2.

			Sentence Region											
			Compatible Verb						*Incompatible Verb*					
			VP1		*NP*		*VP2*		*VP1*		*NP*		*VP2*	
Sentences	*Subjects*		*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
English	American	Gaze duration	308	56	433	90	311	96	340	73	389	51	374	90
		First fixation	219	36	243	28	204	56	207	47	237	40	229	43
		Regressions	7		9		9		3		6		16	
		Second pass	335	180	361	179	252	100	386	202	416	218	357	213
	French	Gaze duration	348	55	412	85	343	39	482	77	468	89	359	72
		First fixation	267	53	257	54	243	63	263	36	262	35	242	58
		Regressions	5		9		8		5		8		16	
		Second pass	334	202	306	325	370	188	500	228	524	294	422	272
French	American	Gaze duration	415	119	398	121	409	136	499	108	443	110	405	97
		First fixation	261	77	246	69	271	63	284	66	259	68	260	77
		Regressions	7		11		10		5		19		11	
		Second pass	393	145	400	195	497	186	447	258	456	235	518	270
	French	Gaze duration	360	110	315	83	342	95	373	101	391	93	331	108
		First fixation	229	46	219	27	223	56	253	32	239	39	225	33
		Regressions	5		7		11		7		21		8	
		Second pass	265	93	344	148	307	133	417	217	407	245	319	232

Note: Measures are given for each of the three sentence regions (VP1 = verb of initial subordinate clause, NP = noun phrase immediately following subordinate verb, VP2 = main verb), as a function of bilingual group, language of sentence, verb type, and sentence region.

sentences where the preceding subordinate verb was optionally transitive (367 msec) rather than intransitive (327 msec). It is noteworthy that this trend was not affected by the native language of subjects (F_1 and $F_2 < 1$). Here again, the analysis of first fixation durations did not reveal any significant effects.

First Pass Interzone Regressions: English Sentences

Table 3 shows the total number of first pass interzone regressive saccades that subjects launched from the subordinate verb, the NP region, and the disambiguating region (the main verb up to the penultimate word of the sentence), to a previous region of the sentence. Given the relatively small number of regressions, data were subjected to an overall analysis, including all three sentence regions.

The analysis of the launch sites of interzone regressions revealed an effect of region, $F_1(2, 48) = 4.56$, $p < .02$; $F_2(2, 24) = 6.10$, $p < .01$, which was qualified by an interaction with sentence type, $F_1(2, 48) = 3.83$, $p < .03$; $F_2(2, 24) = 6.64$, $p < .01$. A Newman-Keuls analysis of the interaction effect revealed significant differences between the two sentence types at the final (disambiguating) region ($p < .05$ by items and by subjects), but not at the preceding NP or subordinate verb. Subjects launched more regressions from the final (disambiguating) region in sentences in which the verb of the initial subordinate clause was optionally transitive than in sentences containing intransitive subordinate verbs. This interaction was not qualified by native language (F_1 and $F_2 < 1$).

Second Pass Reading Times: English Sentences

Mean second pass reading times for the subordinate verb, the beginning of the NP, and the matrix verb of English sentences are given in Table 3. The global analysis of second pass reading times, including all three sentence regions, revealed only an effect of sentence type, significant by subjects, $F_1(1, 24) = 10.06$, $p < .01$; $F_2(1, 12) = 3.94$, $p < .07$. Subjects spent more time re-reading sentences in which the verb of the intial subordinate clause was optionally transitive than those in which it was intransitive. The effect of sentence type was not qualified by region, $F_1 < 1$; $F_2(2, 24) = 2.19$, n.s. It is also noteworthy that the effect of sentence type was not modified by the native language, $F_1(1, 24) = 1.21$, n.s.; $F_2 < 1$. Both groups of bilinguals demonstrated longer re-reading times for sentences that contained subordinate verbs that were optionally transitive in English.

First Pass Reading Times: French Sentences

Independent analyses were performed on the mean first pass gaze durations and first fixation durations obtained at the subordinate verb, the beginning of the NP, and the matrix verb for French sentences. These means are summarized in Table 3.

At the subordinate verb, the analysis of gaze durations revealed an effect of native language, $F_1(1, 24) = 4.95$, $p < .04$; $F_2(1, 12) = 16.80$, $p < .001$, due to longer reading times in the second language. There was a marginally reliable effect of sentence (verb)

type, $F_1(1, 24) = 3.60$, $p < .07$; $F_2(1, 12) = 3.72$, $p < .08$, showing longer gaze durations for "incompatible" than for "compatible" subordinate verbs. This factor did not interact significantly with native language, $F_1(1, 24) = 2.02$, n.s.; $F_2(1, 12) = 2.41$, n.s. The analysis of first fixation durations revealed an effect of native language, significant in the item analysis, $F_1(1, 24) = 2.05$, n.s.; $F_2(1, 12) = 7.39$, $p < .02$, and a trend for the effect of sentence type, $F_1(1, 24) = 3.99$, $p < .056$; $F_2(1, 12) = 3.13$, $p < .10$. First fixation durations tended to be longer in the second than in the native language, and for "incompatible" than for "compatible" subordinate verbs. These factors did not interact (F_1 and $F_2 < 1$).

At the beginning of the NP region, the effects of both native language, $F_1(1, 24) = 8.63$, $p < .01$; $F_2(1, 12) = 11.02$, $p < .01$, and sentence type, $F_1(1, 24) = 6.56$, $p < .02$; $F_2(1, 12) = 4.71$, $p < .05$, were significant, but their interaction was not, $F_1 < 1$, n.s.; $F_2(1, 12) = 1.84$, n.s. Gaze durations were longer in the second than in the native language, and longer following "incompatible" than following "compatible" verbs (417 vs. 357 msec respectively). These effects were restricted to gaze durations; the analysis of first fixation durations revealed no significant effects.

At the matrix verb, only the effect of native language was significant, in both the analyses of gaze durations, $F_1(1, 24) = 4.26$, $p < .05$; $F_2(1, 12) = 5.92$, $p < .03$, and first fixation durations, $F_1(1, 24) = 4.72$, $p < .04$; $F_2(1, 12) = 4.14$, $p < .06$.

First Pass Interzone Regressions: French Sentences

The total number of interzone regressions launched from the subordinate verb, the NP, and the final region to a previous region of French sentences is given in Table 3. A global analysis was performed on the data for all three regions, due to the relatively small number of regressions.

The analysis of the launch sites of regressions revealed effects of region, $F_1(2, 48) = 6.41$, $p < .01$; $F_2(2, 24) = 10.49$, $p < .001$, and of sentence type, at least by subjects, $F_1(1, 24) = 6.06$, $p < .02$; $F_2(1, 12) = 3.29$, $p < .09$, as well as their interaction, $F_1(2, 48) = 3.59$, $p < .04$; $F_2(2, 24) = 5.09$, $p < .01$. A Tukey's HSD test of the interaction confirmed that the two sentence types differed at the NP ($p < .03$ by subjects; $p < .02$ by items) but not at the subordinate verb or final region. Subjects launched more interzone regressions from the NP in sentences where the subordinate verb was incompatible across languages (i.e. intransitive in French but optionally transitive in English) than in sentences where this verb was compatible (intransitive in both languages). This interaction was not qualified by native language (F_1 and $F_2 < 1$).

Second Pass Reading Times: French Sentences

The global analysis of second pass reading times, involving all three sentence regions, revealed effects of native language, $F_1(1, 24) = 5.90$, $p > .04$; $F_2(1, 12) = 11.45$, $p < .01$, and of Sentence Type $\times$ Subjects, $F_1(1, 24) = 4.49$, $p < .04$; $F_2 < 1$. Subjects tended to spend more time re-reading sentences in which the verb of the initial subordinate clause presented incompatible information across languages than sentences with "compatible" verbs (cf. Table 3) and when reading in the second than in the native language.

Discussion

Experiment 2 examined non-native and native readers' parsing of structurally ambiguous sentences. The specific aim was to determine whether non-native readers would be influenced by lexical information from their native language when parsing sentences in their second language. Our data showed that native and non-native readers were similarly sensitive to syntactic ambiguity. Indeed, at the point in the sentence where the ambiguity was resolved, the two groups of readers showed remarkably similar patterns of eye movement behaviour. In spite of this, there was evidence in the data obtained prior to the point of disambiguation that non-native readers were influenced by their native language. This was most apparent in the data for English sentences. There was also evidence in the data for French sentences that non-native readers experienced momentary difficulty when their native language (English) was in conflict with their second language. However, it is not as clear that, for the non-native readers, difficulty in French was linked to their native language. Native readers of French also experienced difficulty at this particular point in the sentence. The results obtained for English and French sentences will be reviewed in turn.

Consider first the case of English sentences. Our results show that both native and non-native readers parse structurally ambiguous sentences incorrectly. This was apparent in the data for both the first reading and for re-readings of sentences. The effect of syntactic ambiguity was apparent during the first pass through the sentence in the pattern of regressive saccades; subjects launched more regressions from the disambiguating region in sentences that were structurally ambiguous up to the verb of the second (main) clause than in sentences that were not. Syntactic ambiguity affected reading times during the second pass through the sentence, with subjects spending more time re-reading ambiguous than unambiguous sentences. These effects were obtained at the point of disambiguation, the matrix verb for the present sentences, and were observed in similar fashion for the two groups of readers. It is noteworthy that syntactic ambiguity in English affected the group of non-native, French bilingual readers. This implies that the bilinguals parsed sentences in their second language in accordance with the lexical constraints of that language, even when their native language dictated opposing constraints. Indeed, the subordinate verbs that were the source of the ambiguity in our English sentences were not ambiguous in the French language. However, there was evidence at the subordinate verb itself that non-native readers were engaged in processing that differed from that of the native readers, and that they were in fact influenced by their native language.

At the subordinate verb, the non-native (French-bilingual) readers were significantly slower to process optionally transitive than strictly intransitive English verbs. One account of this difficulty with the optionally transitive verbs is that the non-native readers were slowed by the greater number of structural options made available by optionally transitive than by strictly intransitive verbs. Indeed, there was a hint of a difference in processing time for the two types of verbs in the group of native readers. A more likely explanation, however, is that non-native readers were slower to process the optionally transitive English verbs because the French equivalents of these verbs were strictly intransitive. To put it another way, when reading in their second language, subjects took time to reflect upon a verb's usage in cases where information from their native

language conflicted with that from their second language. Following the momentary hesitation at the initial point of ambiguity, non-native readers apparently processed sentences according to the constraints of the second language, as revealed by the pattern of behaviour at the point of disambiguation. In summary, the data obtained for English sentences in the non-native group of readers show a localized effect of the native language on second-language processing, at the region where the two languages presented conflicting information. This did not impede the non-native readers from then continuing to process sentences in the same manner as native speakers.

In French, both groups of bilinguals also apparently had difficulty with parsing sentences that presented incompatible information in the two languages—that is, those in which the verb of the initial subordinate clause was intransitive in French but optionally transitive in English. We can note that we did not expect this effect in the native group, given that the sentences did not differ from each other in the French language. It is important to note, however, that the difficulty was apparent immediately after the processing of the subordinate verb, at the NP region. More regressions occurred from the NP, and reading times in this region were longer following incompatible than compatible verbs. Hence, parsing difficulty occurred earlier and was undoubtedly different in nature from that observed for English sentences.

To explain the difficulty observed in French, one could hypothesize that the subcategorization information from English influenced processing in both groups. This is compatible with the data in one aspect, given that our readers apparently quickly realized their error—that is, immediately after having left the verb. It is difficult to rule out this possibility in the non-native (English-dominant) group. For the native group of readers, however, this hypothesis is less plausible. It would imply that the second language was intruding upon the native language, and there was no sign of this in the data obtained for English sentences.

A more likely explanation for the results found in French is that they may be linked to information associated with the verb in *French*, not English. Inspection of our material revealed that many of the French verbs that were optionally transitive in English did not have the same properties as the French verbs that were intransitive in both languages. Specifically, many easily accepted indirect object NPs preceded by a short preposition (*à* or *de*). For example, verbs such as *téléphoner* [to phone], *écrire* [to write], and *démissioner* [to resign] can be, and often are, used in constructions such as *téléphoner/écrire à quelqu'un* [to phone/write to someone], and *démissioner de quelque chose* [to resign from something]. Subjects may have expected this usage of these verbs and thus expected to treat the following NP as an indirect object complement rather than as the head of a new sentential clause. This would explain not only the longer reading times and higher number of regressions we observed, but also why they occurred immediately following the verb. We can note that this type of information has been shown, previously, to have an effect on parsing (Frenck-Mestre & Pynte, 1995).

We ran a control study to determine whether the same pattern results as that observed in French in the main study would obtain for native French readers who had little knowledge of the English language. Sixteen monolingual French subjects participated in the experiment, which was in all aspects identical to Experiment 2, except that these subjects read sentences in French only. The results were highly similar to those obtained

in the main study. French monolinguals demonstrated longer first pass gaze durations at the subordinate verb itself, $F_1(1, 12) = 7.95$, $p < .02$; $F_2(1, 12) = 7.17$, $p < .02$, for "incompatible" than for "compatible" verbs (382 vs. 314 msec, respectively). At the beginning of the NP region, first pass gaze durations tended to be longer following "incompatible" than "compatible" verbs (422 vs. 371 msec, respectively; $F_1(1, 12) = 4.23$, $p < .06$; $F_2(1, 12) = 1.13$, n.s.). These subjects also made more regressions in the case of sentences containing "incompatible" verbs than in the case of sentences containing "compatible" verbs, $F_1(1, 12) = 11.30$, $p < .01$; $F_2(1, 12) = 3.55$, $p < .08$, and this effect was qualified, in the subject analysis, by region, $F_1(2, 24) = 4.21$, $p < .03$; $F_2(2, 24) = 1.97$, n.s. A Newman-Keuls analysis of the interaction revealed that more regressions occurred from the NP region of the sentence in the "incompatible" than in the "compatible" verb condition ($p < .05$ by subjects and items), whereas there was no significant difference in the number of regressions at the subordinate or main verb. The results of this control study thus support our hypothesis that the performance of bilingual subjects in French was most likely to be attributable to characteristics of the French language than to interfering constraints from English.

GENERAL DISCUSSION

Taken together, the results of Experiments 1 and 2 provide an interesting account of bilinguals' reading abilities in their native and in their second language. On the one hand, these results shed light on the parsing strategies of non-native readers when reading in their second language, and how specific these strategies are to the non-native reader. On the other, they pinpoint the influence of the native language on second-language reading.

Experiment 1 examined bilinguals' second-language performance for sentences that were syntactically ambiguous. Our main aim was to determine whether non-native speakers would resolve these ambiguities differently from native speakers. The results did not strongly support this hypothesis. There was some evidence, from the pattern of regressions and first pass reading times, that non-native readers were more likely to attach new elements of the sentence "low"—that is, to attach incoming information to the most recently processed constituent, unless lexical information specifically dictated otherwise. This general strategy was not apparent in our native readers' data. The most salient result to emerge from the experiment, however, was a great influence of lexical information carried by the verb on syntactic processing, which was apparent in the combined data for native and non-native readers.

Experiment 2 examined whether the syntactic analysis of sentences in the second language would be influenced by lexical constraints from the native language in cases where the two languages were in conflict. The experiment thus addressed the question of whether there is "transfer" of native language information during second-language processing. Our results showed a localized effect of the native language, whereby readers hesitated momentarily at the region of the verb when reading in the second language if the verb behaved differently in the native language. Following this brief hesitation, however, the pattern of performance obtained for bilinguals reading in the second language was highly similar to native readers' performance. The pattern of reading we found in the non-native group is parallel to that found by Kilborn (1989) in an on-line study. The

results from that study showed that proficient German–English bilinguals assigned syntactic roles to NVN triplets in a similar manner to native speakers of English, and yet their response times clearly demonstrated that they were influenced by processing strategies from their native language. Our results, showing a localized effect of the native language on second-language performance, thus extend those of previous studies, which have shown an influence of the native language on the second language at a more macro level (cf. Durgunoglu & Hancin, 1992; MacWhinney, 1992; Odlin, 1989, for recent reviews).

Both experiments examined the effect of subcategorization information, provided by the verb, on parsing in the native and in the second language. From the results of both experiments, we can safely claim that this information did in fact affect the on-line parsing of sentences. Our results do not allow us, nonetheless, to make the stronger claim that lexical information actually guides the parser. In Experiment 1, the information provided by the verb affected processing at a critical location—that is, where the sentence structure was disambiguated, but this location was two words downstream from the verb. Thus it is possible that the effect of lexical information had time to come into play during this interval, rather than being implemented immediately (for a discussion, cf. Frazier, 1987, 1990).

To summarize, we have presented evidence that bilingual readers perform a complete syntactic parsing of the sentence when reading in their second language. Non-syntactic information, such as lexical information carried by the verb, apparently influences the initial reading of sentences in the second language. However, the latter cannot be said, from the present results, actually to play a guiding role in parsing. Our results also hint at parsing strategies specific to non-native processing. One such strategy appears to be a "local attachment" strategy, involving the attachment of new elements of the sentence to the most recently processed constituent. Lastly, we have demonstrated that the bilingual's native language can produce a localized effect on sentence processing in the second language.

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APPENDIX

Experimental Sentences Presented in Experiment 1

For each sentence, noun phrase attachment of the prepositional phrase is given outside parentheses and verb phrase attachment inside parentheses.

1. *Il exclut les conseillers du ministre (du tribunal) mais ils reviennent le lendemain.*
2. *Elle écarte les assiettes du repas (du bord) et elle commence à nettoyer.*
3. *Elle protège les enfants du village (du danger) mais ils ne s'en rendent pas compte.*
4. *Ils avertissent la police du quartier (du crime) puis se félicitent de leur action.*
5. *Il soupçonne l'ambassadeur d'Indonésie (d'espionnage) mais il n'est pas certain des faits.*
6. *Elles retirent les vêtements du bébé (du placard) et les placent dans un carton.*
7. *Il accuse son chef de service (de meurtre) mais il ne peut pas fournir de preuve.*
8. *Elle recouvre la table de cuisine (de fleurs) avant de quitter la pièce.*
9. *Ils informent les gardes du palais (du projet) et partent à la recherche du roi.*
10. *Il inculpe les gardiens de prison (de vol) mais le juge ne les condamne pas.*
11. *Elles remplissent la salle de séjour (de fumée) puis ouvrent les fenêtres.*
12. *Elle aspergeait le tapis de bain (de bière) alors que sa mère la regardait.*
13. *Il espionne le garde du corps (du balcon) alors que le garde parle à un ami.*
14. *Elles cachent leur chien de race (de honte) après ce qu'il a fait.*
15. *Ils regardent la vendeuse de robes (de travers) puis ils quittent le magasin.*
16. *Elle casse les verres de cristal (de rage) puis elle claque la porte.*
17. *Ils frappent les enfants de coeur (de colère) sans que personne ne réagisse.*
18. *Il rate le train de nuit (de peu) et décide alors de chercher un hôtel.*
19. *Elle arrive à l'aéroport de campagne (de justesse) et fait enregistrer ses bagages.*
20. *Il emporte la carte de crédit (de surcroît) et dit au revoir à sa maîtresse.*
21. *Il recrache la viande de boeuf (de dégoût) puis fait appel au maître d'hôtel.*
22. *Elle aperçoit le marchand de fruits (de dos) mais ne rentre pas dans le magasin.*
23. *Il connaît la femme de chambre (de vue) mais ne se rappelle plus son nom.*
24. *Elles admirent le château de sable (de loin) alors qu'elles sont sur la plage.*

Experimental Sentences Employed in Experiment 2

"Incompatible" verbs (optionally transitive in English, intransitive in French) are outside of, and "compatible" verbs (intransitive in both languages) are inside parentheses.

1. When the musician played (came) the white grand piano was in the centre of the stage.
   Quand le musicien jouait (venait) le beau piano blanc était au centre de l'estrade.
2. As soon as Bill phoned (arrived) his young wife began preparing their dinner.
   Aussitôt que Jean téléphona (arriva) sa jeune femme commença à faire le repas.
3. Wherever Sarah walked (went) her pretty miniature poodle followed happily behind.
   Où que Sarah marchât (allât) son joli caniche nain suivait derrière gaiement.
4. Because the school boy fought (excelled) the other small children did not like him.
   Du fait que l'écolier luttait (excellait) les autres jeunes enfants ne l'aimaient pas.
5. The minute George entered (appeared) the large reception hall exploded with laughter.
   A l'instant où Georges entra (apparut) la salle de réception éclata de rire.
6. Although the girl resisted (hesitated) the temptation to eat was very strong indeed.
   Bien que la fille résistât (hésitât) la tentation de manger fut la plus forte.
7. Each time the child pedalled (fell) her old blue bicycle made a tremendous noise.
   Chaque fois que l'enfant pédalait (tombait) sa vieille bicyclette bleue faisait du bruit.
8. When the president resigned (died) his position at IBM had to be filled rapidly.
   Lorsque le président démissionna (mourût) son poste à IBM dut être pourvu rapidement.
9. Knowing that the gypsy cheated (lied) even his best friend refused to trust him.
   Sachant que le gitan trichait (mentait) même son meilleur ami refusa de payer sa dette.
10. Right when Mary wrote (arrived) her sick old aunt died in the hospital.
    Au moment où Marie écrivait (arrivait) sa vieille tante malade mourait à l'hôpital.
11. Every time that the dog obeyed (barked) the pretty little girl showed her approval.
    Chaque fois que le chien obéissait (aboyait) la jolie jeune fille montrait sa joie.
12. When the professor left (spoke) the small lecture room vibrated with noise.
    Quand le professeur partait (parlait) la salle de cours vibrait de bruit.
13. Whenever the boy disobeyed (lied) his poor old grandmother had to punish him.
    Lorsque le garçon désobéissait (mentait) sa pauvre vieille grand-mère devait le punir.
14. The day that the woman divorced (departed) the handsome Texan cowboy jumped for joy.
    Le jour où la femme divorça (partit) le beau cowboy texan sauta de joie.
15. As soon as the pilot landed (came) the new supersonic jet was removed from the runway.
    Dès que le pilote atterrit (arriva) le nouvel avion supersonique fut enlevé de la piste.
16. Though the cat fought (lived) the good Italian veterinarian doubted about its meanness.
    Bien que le chat lutta (vécut) le bon vétérinaire Italien doutait de sa méchanceté.