Ambiguities and anomalies: What can eye-movements and event-related potentials reveal about second language sentence processing?

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Second language sentence processing is examined here in light of several monolingual psycholinguistic models of parsing, as well as that of linguistic theories specifically adapted to account for second language acquisition in adult learners. We first examine studies that have primarily recorded eye-movements to trace syntactic processing. Syntactic-ambiguity resolution is used in these studies to address various current models of parsing, both in monolinguals and bilinguals. To illustrate how these models can be tested, we discuss a particular type of structural ambiguity: reduced relative clauses. Thereafter, we focus our attention on studies that have recorded event-related potentials during the processing of spoken and written sentences in bilinguals. In these studies, the accent is placed upon how semantic and syntactic anomalies, rather than ambiguities, are treated. We conclude with a quick comparison of these two approaches.

In a recent paper, White (1997) raised the interesting issue of the relationship between linguistic theory and research on second language acquisition. As she quite correctly states, theory is ever-changing and subject to sometimes major upheavals. Linguistic theory is no exception. What are the implications for second language research? The answer to this question is not as immediately apparent as it may seem. As stated by Bialystok "…the field [of second language acquisition] is populated by groups bearing hyphenated allegiances: sociolinguistics, applied linguistics, psycholinguistics, educational linguists, and so on. Although it is clear that each relies in its own way on the parent field of linguistics, it is not at all clear, and certainly not consistent, what role linguistics plays in each research program." (Bialystok, 1997, p. 56). To further complicate matters, within each of these fields there is widespread debate about just which linguistic theory is the best monolingual model of linguistic achievement (cf. Frazier & Clifton, 1996; MacDonald, Pearlmutter, & Seidenberg, 1994; for two influential and opposing psycholinguistic viewpoints).

In the present chapter, we focus our attention on the processing of a particular syntactic ambiguity, in American-French bilinguals who acquired their L2 (French) past early childhood. The study can be cast in the framework of (at least) three theories, one a largely influential linguistic theory that has undergone several major changes over the years (Chomsky, 1981; 1986; 1993), one a major psycholinguistic theory which has undergone its own upheaval lately (Frazier, 1987; Frazier & Clifton, 1996) and the last an experience-based psycholinguistic model which is facing serious challenges at present from monolingual data (Cuetos, Mitchell, & Corely, 1996; Mitchell, 1994). Indeed, given the numerous re-appraisals of monolingual (psycho)linguistic models, any attempt to interpret second language data in terms of these models can pose quite a challenge.

General issues of parsing

The study of how readers initially resolve structurally ambiguous sentences has proven extremely useful, in monolingual research, to the understanding of the general processes underlying parsing. Several monolingual studies have used this approach to examine the influence of lexical information on initial parsing decisions. For example, the role of *verb argument structure* on ambiguity resolution has been examined in numerous studies, via the recording of behavioral measures such as eye movements or button-presses in self-paced reading (Boland & Boehm-Jernigan, 1998; Ferreira & Henderson, 1990; Frenck-Mestre & Pynte, 1995; 1997; Mitchell, 1989; Mitchell & Holmes, 1985; Trueswell, Tanenhaus, & Kello, 1993), or of event-related brain potentials (Osterhout & Holcomb, 1992; Osterhout,

Holcomb, & Swinney, 1994; see also Friederici & Frisch, 2000). Other studies have used syntactic ambiguity resolution to determine the role of *the relative frequency of syntactic structures* associated with a particular lexical element (for various viewpoints see Holmes, Stowe, & Cupples, 1989; MacDonald et al., 1994; Pickering, Traxler, & Crocker, 2000; Trueswell & Kim, 1998). Yet others have examined the role of *thematic information* (McRae, Ferretti, & Amyote, 1997; Tanenhaus, Carlson, & Trueswell, 1990; Taraban & McClelland, 1988; Trueswell, Tanenhaus, & Garnsey, 1994) and the use of *referential context* (Altmann, Garnham, & Dennis, 1992; Clifton, Bock, & Rado, 2000; Ni, Crain, & Shankweiler, 1996) on immediate parsing decisions.

These issues have been examined via the processing of several types of syntactic ambiguities. We first illustrate them via a "classical" syntactic ambiguity, presented in sentences 1 through 3, below. This particular ambiguity is also of particular interest to the present study, given syntactic constraints of the English and French languages, which we will discuss shortly.

1a. *The student graded <u>by the professor</u> received …*
1b. *The paper graded <u>by the professor</u> received …*
2a. *The businessman loaned money at low interest <u>was</u>…*
2b. *Only the businessman loaned money at low interest <u>was</u>…*
3a. *The shrewd heartless gambler manipulated <u>by the dealer</u> had..*
3b. *The young naive gambler manipulated <u>by the dealer</u> had …*

This particular structure, involving a reduced relative clause, has been studied extensively in English, and, to a lesser degree, in French. Bever (1970) immortalised it for all psycholinguists with the famous example "The horse raced past the barn fell." We first outline the monolingual results as concerns its processing and the models that can account for them, and then proceed to a discussion of how American-French bilinguals process a similar structural ambiguity in their second language (French). The data will be discussed in terms of the models that have been appealed to to account for them.

According to one theoretical stance, whereby syntax is the predominant factor affecting immediate parsing decisions (Frazier & Clifton, 1996), monolingual (and indeed all) readers should show systematic difficulty upon encountering the disambiguating element of this structure (underlined in the examples above). This would be due to readers using an initial heuristic strategy of projecting the simplest syntactic structure, which would be a main verb interpretation of the first VP (cf. Kimball's 7 strategies, 1973). Indeed, it has been shown in some studies that readers do have notorious difficulty with a reduced relative structure as compared to an unambiguous control sentence (Ferreira & Clifton, 1986; Rayner, Carlson, & Frazier, 1983). In light of this flavor of "syntax first" model, this difficulty should be experienced quite independently of other factors, such as the relative frequency of the structure, the particular properties of the different lexical items it contains, or the referential context in which it occurs. Any facilitation provided by these extra-syntactic factors would be attributable to the greater ease of *re-interpretation* of the initially built structure. However, a quick review of some recent monolingual studies shows this not to be a completely resolved issue.

Consider the examples provided in 1 through 3. If readers obey strictly syntactic heuristic principles, they should experience equal difficulty with the first version (a) as the second (b) of each of these sentence pairs. However, as illustrated by various authors, extra-syntactic factors can in fact influence processing, rendering the second version of each of these pairs easier to process. The animacy of the first noun phrase (illustrated by examples 1a and 1b) can reduce readers' likelihood to treat this noun as the subject of the initial verb (MacDonald, 1994; Trueswell et al., 1994; but see Ferreira & Clifton, 1986) thus rendering less likely a main clause interpretation in the case of 1b than 1a.. The lexical properties of the verb itself may also play an important role in determining readers' initial choice of structure, according to some (MacDonald et al., 1994). In the same vein, the role of the thematic constraints of the first NP as well as contextual information have been investigated. Under experimental circumstances where readers are given single thematically independent sentences one might indeed predict difficulty, as shown by behavioral measures and/or electrophysiological evidence, upon the reading of the disambiguating region of sentences such as those illustrated in examples 2 and 3. A quite different result might be expected, however, when readers are given contextual information, such as the focus particle "only"

present in example 2b but not in 2a, or when given more extended referential information when they read sentences in context. Just this effect has been obtained, in various on-line monolingual studies, showing that 2a is in fact harder to process than 2b (Crain & Steedman, 1985; Ni et al., 1996; but see Clifton, et al., 2000, for an opposing view). The same result has been obtained when the context is provided by a sentence rather than by a single word (Altmann, et al., 1992). Furthermore, numerous on-line studies have now provided evidence that semantic and/or thematic information can reduce a reader's likelihood to be "led up the garden path." The examples depicted in 3a and 3b illustrate this. Readers of English experience less difficulty with sentences such as 3b than with those such as 3a, due to the semantic information present in the sentence onset (McRae, Ferretti, & Amyote, 1997; Taraban & McClelland, 1988). The above monolingual studies thus strongly question the hypothesis that readers initially form a "serial, strictly syntactic" parse of structures, and propose, rather, lexically and/or referentially-based models of parsing (for recent models see Macdonald, Pearlmutter & Seidenberg, 1994; but see Pickering et al., 2000; Clifton et al., 2000, for contrary viewpoints).

Bilingual studies of on-line parsing: Evidence from eye-movements

In the same vein that monolingual models of parsing can be tested via the processing of syntactic ambiguities, so can second language research gain from this approach. Note, first, that the same factors that are prone to influencing immediate syntactic processing in the native language will affect second language processing, provided that the reader has sufficient knowledge of the second language (Dussias, 2001; Frenck-Mestre, 1997; 2002; Frenck-Mestre & Pynte, 1997; Hoover & Dwivedi, 1998; Juffs & Harrington, 1996; see also Fernandez, 1998, for off-line second language studies of syntactic ambiguity resolution). Nonetheless, just what choice the reader will make upon encountering a syntactic ambiguity in the second language can provide valuable information as concerns specifically second-language issues. This can be illustrated by the examples 4a and 4b, provided below :

> 4a. *Le sous-marin **détruit** pendant la guerre **a coulé** en quelques secondes.*
> *The submarine **destroyed** during the war **sank** in a few seconds.*
> 4b. *Le sous-marin **détruit** pendant la guerre **un navire** de la marine royale.*
> *The submarine **destroys** during the war **a ship** from the royal navy.*

Both of these sentences are syntactically legal in the French language. They are both structurally ambiguous, and in the present case equally plausible. They differ, however, as concerns readers' initial preference, manifested at the disambiguation point underlined in the examples. The structure presented in 4a, involving a reduced relative clause, where the element following NP1 is not the main verb but a past participle form which is the verb of the reduced relative clause, is known to cause difficulty for readers in the absence of extra-syntactic cues, as outlined above. Thus, French native speakers can be expected to experience greater difficulty at the disambiguation of structure 4a than structure 4b (i.e., upon reading the verb of the main clause (a coulé) than the direct object NP (un navire), as has indeed been shown with structures similar to these (cf. Pynte & Kennedy, 1993). This is not, however, as immediately apparent for native English speakers, when reading in French, as we will now outline. While 4a may indeed pose some difficulty for native English speakers, 4b may pose just as great a problem. Whereas 4b is both permissible and plausible in French, it is generally considered to be an ungrammatical structure in English. Indeed, in English, it is generally not permissible to separate the case assigner from the element receiving the case (Haegeman, 1994), that is, to displace the direct object NP from the case-assigning VP[1]. This is not the case for French, as direct object NPs may, but need not, be adjacent to the case-assigning VP[2]. We will elaborate upon this momentarily. Structure 4a is permissible in both English and French, and is both structurally equivalent and equally ambiguous in the two languages. Of the two structures (4a and 4b), it is the syntactically more complex. For 4b, while it is the syntactically simpler structure, it generally violates the constraints of the English language. Which of these considerations will prevail for native English speakers reading in French? Should they find it easier to process 4a than 4b despite the increased syntactic complexity of the former of these sentences? Might the structural ambiguity of 4a be blocked for beginning English-French bilinguals if they adopt the parameters of their native language when reading French? Otherwise stated, might they

systematically adopt the reduced relative reading of the sentence when they encounter the prepositional phrase thus rendering the declarative interpretation disprefered?

Some evidence on this matter has been provided by White (1989a, 1989b; 1991). White has argued that French ESL learners should incorrectly assume that 4b is a licensed structure in English, given the syntactic differences across French and English. In line with this, White found that French readers rated structures similar to that presented in example 4b as being grammatically acceptable, and found it difficult to distinguish between this structure and the correct English one, where the object NP is adjacent to the verb (such as "The submarine destroyed a boat during the war."). White's results thus clearly demonstrate the influence of the native language on second language parsing.

How then might one expect English learners of French to process structure 4b? White argues that French readers will have difficulty rejecting structures such as 4b, where there is an intervening element between the case-assigning VP and the object NP, due to French having [–strict adjacency], whereby it is permissible to displace the object NP. White (1989b, Chapter 6) outlines her argument in terms of "parameter setting" whereby French learners of English must "reset" the values of this parameter, to [+strict adjacency], to accommodate for the more restricted set of sentences possible in English[3]. White accounts for her results in the framework of universal grammar and the inability of adult learners to access UG and to properly reset parameters that were set by the properties of the speaker's native language. Indeed, for a French speaker to consider sentences such as 4b as ungrammatical in English s/he would have to revert from a "superset" grammar to a more restricted "subset" wherein only one of the two grammatical possibilities is available. This is considered to be quite difficult[4]. In light of this line of argumentation, English learners of French should, conversely, experience difficulty with structure 4b, for the mirror reason. That is, if they apply the strict adjacency principle from English (and the subset principle), they should initially adopt a more restricted grammar of French and should experience difficulty in interpreting structure 4b. If this principle is applied "blindly," then English native speakers should experience greater difficulty with structure 4b than 4a, even though the former is the simpler, syntactically speaking, of the two. To examine this question, we examined the processing of structures 4a and 4b, with novice English-French bilinguals via the recording of eye movements (Frenck-Mestre, 1998).

The results of our experiment (Frenck-Mestre, 1998) clearly reveal that beginning English-French bilinguals do not treat the ambiguous structures illustrated by examples 4a and 4b in the same manner that native French readers do. First, it is notable that American readers showed longer reading times as compared to French readers at the prepositional phrase region following the first verb (in the examples "during the war"), for both sentence structures. This would be expected if the English-dominant bilingual readers projected a main clause structure but then immediately revised this hypothesis due to the absence of a noun phrase following the verb. This interpretation of the data was strengthened by the results obtained at the disambiguation point (underlined in the examples 4a and 4b). The group of English-French bilinguals experienced considerably more difficulty, as manifested by longer reading times, when the disambiguating element forced a main clause interpretation of the sentence (example 4b) than a reduced relative structure (example 4a). Moreover, as compared to French readers, they demonstrated considerably longer reading times for the main clause reading. The data for the group of French readers did not in fact show a difference in processing time for the two structures during the first reading of the sentence, but only in the measure of "total" reading times (i.e., the summation of all fixations in a specified region of the sentence, including the first time the eye enters the region and all subsequent re-readings thereof).

Which available theory best accounts for the data?

In view of certain current monolingual models of language processing, it would appear that our data pose some difficulty. In contrast to models that assume a heuristic parser, which will systematically adopt the least complex of two alternative structures, we found that our participants did not show an immediate preference for the syntactically less complex structure of two alternatives. Quite to the contrary, when our participants were confronted with structurally ambiguous sentences such as illustrated in 4a and 4b, we found that our bilingual readers showed evidence of difficulty with the syntactically *less complex* structure when reading in their second language. Moreover, the results from our French monolingual control subjects reading in their native language did not show nearly as strong or

as immediate effects of syntactic complexity as has been reported in previous monolingual studies.

Monolingual theories of parsing which posit that the *frequency* of structures (as opposed to the syntactic complexity thereof) is a crucial element in determining the difficulty of processing (cf. MacDonald, 1997; MacWhinney, 2001; Mitchell, 1989; Mitchell, Cuetos, Corley, & Brysbaert, 1995) may provide a better framework for understanding the pattern of results we obtained, both in the monolingual group of readers and in the relatively inexperienced bilingual group. Past exposure to and experience with a language and its properties is a key factor in this type of model, which provides quite a different theoretical stance on syntactic processing as compared to "syntax-first" accounts.

Consider, first, the constraint satisfaction model forwarded by MacDonald et al. (1994). From the vantage point of this model, it may be considered quite logical that the reduced relative structures we studied did not produce strong effects in the monolingual group of subjects. Quite a number of the verbs that we selected were frequently used as adjectives (for example "instruit," "maudit" "distrait," among others). In line with MacDonald et al.'s prediction that the frequency of structures will directly affect processing difficulty, this would decrease readers' likelihood to treat this word as the main verb of the phrase and facilitate the processing of a reduced relative structure following a head such a "Le prêtre instruit …". Otherwise stated, our French readers may have experienced little difficulty with the reduced relative sentences due to their having previously processed this structure for the particular verbs we chose[5]. The results obtained in the bilingual group can be explained along similar lines. That is, given that the English language rarely admits the structure presented in example 4b, where the direct object complement is separated from its case assigning verb, our American-French bilingual readers should have had little experience with this structure in their native language (English) and thus be less likely to project it when an alternative structure is available.

Another statistical model of parsing is that known as the "linguistic tuning hypothesis" forwarded by Mitchell and colleagues (Mitchell, 1989; Mitchell, et al., 1995). The model predicts, in similar fashion to MacDonald et al. (1994), that the amount of difficulty a reader will experience when parsing a structure will be directly related to the amount of prior experience that s/he has had with it. It has been forwarded as an explanatory model of cross-linguistic variation as concerns syntactic ambiguity resolution (cf. Cuetos et al., 1996; Frenck-Mestre & Pynte, 2000a; 2000b, for recent reviews). The model has direct bearing upon the results found in our bilingual group of readers. First, these readers should, in terms of the model, experience greater difficulty with structures such as 4b given that the native language of these bilinguals does not afford them with much experience with this structure, and that they were relatively inexperienced in the French language. Second, a prediction can be made as concerns the performance of these bilingual subjects as they gain experience in French. As stated expressly in Cuetos et al. (1996, p. 175): "The model predicts that parsing preferences will change if, during some period prior to testing, the reader or listener has been exposed to an unusual preponderance of one ambiguity resolution rather than another." From this, we could expect bilingual subjects to show changes in immediate parsing decisions when reading in their second language if, indeed, they receive linguistic input which differs from that present in their native language (cf. Frenck-Mestre, 2002, for a discussion). As concerns the ambiguity studied in the present paper, we could predict that with greater experience English readers of French would accept the -strict adjacency criterion in French and subsequently have lesser difficulty processing structures where the object NP is displaced from its case assigning VP. While we presently only have preliminary data on this question, the results from a small group of more advanced English-French bilinguals suggests that the above prediction holds. The trend in this more advanced group is to behave like their French counterparts when processing the ambiguous structures presented in 4a and 4b. It is important to note, nonetheless, that the linguistic tuning hypothesis has not proven capable of accounting for recent monolingual results (cf. Mitchell & Brysbaert, 1998). That is, when on-line monolingual processing is examined for materials modelled closely on corpora-based sentences, the on-line preferences are quite the opposite that which would be predicted by the statistical frequency of structures in the corpora. As such, although attractive, the model appears to be in need of further elaboration prior to being accepted as a general framework.

Then again, we can ask whether the data we report for our bilingual readers can be explained in terms of parameter setting, such as suggested by White (1989a, 1989b). First,

the interested reader is referred to a recent discussion by Fodor (1999) as concerns the hypothesis of a "set and ready" mechanism which would allow the human parser to determine the correct parameters to describe the grammar of his/her language. In sum, Fodor outlines the impossibility of any such automatic mechanism based on superficially recognizable cues for natural language grammars. She suggests that the only psychologically valid "triggering" mechanism is part and parcel of parsing. Regarding the acquisition of second language grammars by adult learners specifically, Fodor suggests a "processing" account that is not at odds with the frequency based accounts that were outlined above. She posits that the increased use or, conversely, disuse of parameter values via parsing will have a direct impact upon the "activation" levels of these values (not at all unlike the model forwarded by MacDonald et al., 1994; MacRae et al., 1997). The stronger L1 parameter values would be hard to overcome in an initial state, thus producing the type of interference observed by White and as we and many others have observed for various structures (cf. Durgunoglu, 1997; Dussias, 2001; Fernandez, 1999; Frenck-Mestre, 2002; MacWhinney, 1997, for reviews). When the adult learner parses L2 sentences with the incorrect L1 grammar, s/he will eventually be led to disfavour L1 values and apply those parameter values of the L2 that enable a correct parse of the structure, thereby increasing the "activation" levels of the latter and (perhaps, with a vast amount of exposure) decreasing the former. Hence, through parsing of structures specific to the second language the adult learner may learn a new set of parameter values along with the second language, which would become increasingly strong with second language use. Our data from English-dominant readers of French, who have had relatively little experience parsing their second language in comparison to their first, can easily be accounted for in such terms. Note, however, that the difference between the account proposed here by Fodor and that proposed by frequency-based models (i.e., MacDonald et al., 1994; McWhinney, 1997; Cuetos et al., 1996) is not readily apparent.

Robertson and Sorace (1999) provide an interesting discussion of what might be driving the results obtained by White (1989a). They recast White's data in terms of optionality theory. Robertson and Sorace make the parallel between the results they obtain with German adult learners of English as concerns verb placement and those obtained by White for French learners of English regarding adverb placement. These authors suggest that rather than assume an all-or-none mechanism whereby native language parameters are reset to those of the second language, that optionality at the level of competence persists in "inter-language" grammars. This suggestion stems from the observation that residual constructions from the native-language grammar (in the case of Robertson & Sorace, V2 constructions from German) are seldom systematically observed. Great variations exist both amongst learners, and within a learner as concerns the frequency and manner in which native-language constraints are applied. The authors find that the principles and parameters model, while able to broadly explain the pattern of interference from the native language on second language processing, is inadequate to explain this variation. They appeal therefore to the minimalist program (Chomsky, 1993) in the terms of the model set out by Eubank (1993/4) of interlanguage gramm This line of argumentation might also be applied to the data for English-French beginning bilinguals we obtained. Although, to truly adopt this type of model one need also examine individual variation as well as group data.

Lastly, in line with the idea that individual variation need be accounted for, we might note that the conclusions we have drawn are based on group results. It goes without saying that there is always considerable variation between participants when any measure of processing is recorded, be it on-line reading times of various natures (self-paced reading, eye-movements) or off-line preferences (questionnaires, sentence completion, etc.). It is the intention of experimental psycholinguistics to go beyond this level of individual variation and, through inferential statistics, draw conclusions from group data whenever licensed to do so. This is not always assumed to be a natural choice. While much can be learned from the study of individual differences (cf. Segalowitz, 1997, for a recent review), and while it is a truism to state that adult learners of a language are a heterogeneous group, it is the present author's intention to gain an understanding of the "larger" picture. Theories of sentence processing must indeed take into account changes that occur in parallel to readers' experience with a language, as highlighted by many (MacDonald et al., 1994; MacWhinney, 1997; Mitchell, 1994). We believe that group data can provide as important information in this regard as individual variation, provided one either follow the progress of a particular group, or, as we have attempted, take a cross-sectional look at data from learners with more or less "parsing"

experience in their second language. This has indeed proven useful in many a prior study of second-language sentence processing.

What can other measures tell us about L2 sentence processing ? : Evidence from event-related potentials.

Up to now we have discussed evidence primarily from studies that used eye-movements to examine native and second language sentence processing. Eye-movements indeed provide a rich and multidimensional on-line record of the process(es) a reader is engaged in. Initial reading of different parts of the sentence can be broken into "first-fixation" (i.e., the amount of time spent from the eyes' initial landing in a region until a new saccade is engaged) and "gaze duration" (i.e., all fixations in a region prior to the eyes exiting the region). Moreover, the fore-mentioned "first pass" measures can be compared to later, re-readings. Whereas the initial reading of an element of the sentence is often considered to reveal readers' first choice as concerns lexical access and/or parsing, subsequent re-readings are more often equated with re-analysis and/or repair processes. In addition to these RT measures, the pattern and frequency of regressive eye-movements can be used to understand how the reader untangles difficult and/or unexpected structures. We have seen how different theories of parsing can be put to the test by recording readers' eye-movement patterns, and how comparisons can be made between bilingual readers' second language processing and native-language processing. There exists, however, another rich, multidimensional, on-line trace of syntactic processing which is the recording of event-related scalp potentials during the visual (word-by-word) and/or auditory presentation of sentences. It is of interest to see whether ERP studies provide complementary information to that provided by eye-movement studies. We shall therefore take a quick look at various ERP studies, as they relate to sentence processing and bilinguals.

Semantic anomalies: Variations in the N400 component

In an early study, Meuter, Donald and Ardal (1987) compared the ERP trace obtained in the first (English or French) and second (French or English) language of two groups of fluent bilinguals while reading sentences. The authors chose to examine variations in the N400 component, as produced by the sentence-final word of semantically anomalous sentences compared to a semantically acceptable ending. The question of interest was whether the "N400 effect" would be obtained in the second language, and whether it would be similar in latency and amplitude to that obtained in the first language. Semantically anomalous sentence-final words produced an N400 effect in both the native and second language. The authors reported a trend for the N400 effect to be smaller in the second than native language. However, this held true at only one electrode site, and for one group of bilinguals only. As such, no firm conclusions can be drawn from this preliminary study about differences in semantic integration processes in the native and second language (as indeed none were). In a subsequent study, Ardal, Donald, Meuter, Muldrew, and Luce (1990) re-examined this question, both in another group of late bilinguals and in a group of "early" bilinguals (mean age of L2 acquistion was 7.3 years). The authors again found an N400 effect in the second as well as native language, that is, a larger N400 to semantically anomalous than semantically acceptable sentence-final words. However, as in the previous study, the N400 effect obtained in the second language differed from that found in the native language, having a slightly later onset in the L2 than in the L1. Moreover, the bilinguals showed a trend for a later onset of N400 in both languages as compared to monolingual controls. No significant differences in the ERP record were found between the "early" and "late" bilingual groups. The tentative conclusion from this study was that semantic integration processes are affected by proficiency in a language, and will be reflected by the time course of electrophysiological measures of processing. One caveat is nonetheless in order; the native language of the bilinguals in this study varied considerably. As is well known (and as we have shown here, earlier in the chapter), interactions between the bilingual's native and second language are numerous. The conclusions from Ardal et al. (1990) study must thus be considered with some caution.

In several more recent studies, ERPs were again used to measure semantic integration processes during sentence processing in the second language (Hahne, 2001; Hahne & Friederici, 2001; Sanders & Neville, 2003; Weber-Fox & Neville, 1996). These studies also looked at syntactic processing, which will be discussed momentarily. The general pattern of these studies seems to be that, depending upon proficiency in the L2, the

N400 effect (as classically produced by semantically anomalous sentence endings or medial words (e.g., "The volcano was *eaten*" or "The scientist criticized Max's *event* of the theorem") in comparison to semantically acceptable sentences (e.g., "The bread was eaten" or "The scientist criticized Max's *proof* of the theorem"), or, more recently, by sentence-medial non-words ("bokkers") compared to real words ("bottles")) will be equivalent in amplitude and latency in the second language of bilinguals to that found in the L1 for native speakers. Note that for less proficient L2 speakers, the amplitude of the N400 effect is often smaller and its peak delayed compared to that obtained in the native-language (Hahne, 2001; Weber-Fox & Neville, 1996), thus rejoining the results reported in earlier studies.

In sum, those studies which have recorded ERPs (auditory and visual) to examine L1 and L2 sentence processing at the semantic level show basically indistinguishable patterns for the two languages for proficient bilinguals, and relatively minor differences between the L1 and L2 for less proficient bilinguals.

Syntactic anomalies : Variations in the N400 component

The above mentioned bilingual studies used the N400 component to index the immediate semantic integration of words in visually and/or auditorily presented sentences. Since the initial finding of Kutas and Hillyard (1980) in monolinguals, this is indeed the most often reported interpretation of variations of the N400. Note, however, that recent work by Osterhout and collaborators (McLaughlin, Osterhout, & Kim, submitted; Osterhout, McLaughlin, Kim, & Inoue, in preparation;) has suggested that in early stages of learning a second language as an adult, the N400 may not be restricted to the detection of semantic anomalies. Osterhout's group has found that number agreement errors in the second language (i.e., between the subject of the sentence and the subsequent verb) will initially produce a variation in the ERP trace that has all the characteristics of an "N400 effect", for young adults who have just begun to learn a second language. With more second-language experience this effect diminishes, to be replaced by a more canonical syntactic marker in the ERP record. This highly interesting line of work should be followed by any researcher endeavouring to understand the development of second-language sentence processing in adults.

Syntactic anomalies : Variations in early anterior negativity and P600

Two major ERP laboratories, one in the U.S. and one in Germany, have recently provided the literature with a series of papers on second-language syntactic anomaly processing (Hahne, 2001; Hahne & Friederici, 2001; Sanders & Neville, 2003; Weber-Fox & Neville, 1996). These papers have all addressed the issue of the "critical period hypothesis" in one way or another, comparing either "early" and "late" bilinguals, or the performance of "late" bilinguals on semantic and syntactic anomaly detection to that of native speakers.

In one of these studies (Weber-Fox & Neville, 1996), direct comparisons were made between five groups of Chinese-English bilinguals, ranging from "early" (as early as from infancy) to "late" acquirement of the second language, in relation to the processing of illegal structures in English. Illegalities were of various sorts, including phrase-structure violations and subjacency errors (as in "The scientist criticized Max's of proof the theorem"). The authors found a high level of performance on behavioural tasks for all groups of bilinguals (at least 85% correct). Several different time windows were considered in the electrophysiological trace. A rather complex pattern of results emerged. At the earliest window (50-250 ms, or "N125"), the three groups of "early" bilinguals did not show a significantly larger response to illegal structures whereas the two groups of "late" bilinguals and the monolingual control group did. However, whereas the monolingual participants showed a hemispheric asymmetry, with a larger response at left anterior sites, the late bilinguals showed a bilateral response which was nonetheless larger over the right hemisphere. The latency of the "N125" was also delayed in the two groups of late bilinguals compared to monolinguals. As such, the authors concluded that the early negativity found in the late bilingual groups was not the "early anterior negativity" associated with aspects of syntactic processing. At a later window, often associated with N400 (300-450 or 300-500 ms after word onset), phrase structure violations produced an increased negativity in all bilingual groups as well as in the monolingual controls. Again, however, in the two groups of bilinguals who acquired their L2 after age 11, the typical "signature" of a greater left hemisphere effect was absent. Finally, in the time window associated with the P600 (i.e., 500 - 700 ms and 700 - 900 ms; cf. Osterhout, & Holcomb, 1992; Osterhout, McKinnon, Bersick, & Corey, 1996)

while the three groups of "early" bilinguals showed a response comparable to that found in monolinguals for this type of violation, the two groups of late bilinguals showed greater positivity to illegal structures only in the later time window (700 - 900 ms), and the amplitude of the P600 was smaller than that found for monolingual controls. The authors suggest that, at least for the types of syntactic anomalies they studied, only very early acquirement of a second language enable bilinguals to acquire the skills necessary to detect and process them in native-like fashion. Note, however, that none of the bilingual groups showed a "typical" early anterior negativity. Moreover, the two groups of late bilinguals did show increased "N400" as well as "P600" responses to illegal structures, even if the latter effect was delayed in comparison to the early bilinguals and monolinguals. As such, the differences across the bilingual groups were in amplitude and latency rather than in nature. In a subsequent study (Sanders & Neville, 2003) the ERP trace to auditorily presented materials was compared for monolinguals and Japanese-English late bilinguals. For the bilinguals, no differences in the ERP trace were found between "syntactic" strings (i.e., basically "jabberwocky" sentences where the syntactic class of elements in the sentence was maintained and respected English syntax, but were otherwise meaningless) and "acoustic" strings (which carried neither syntactic nor semantic information). Monolingual controls, however, produced differences across these conditions, both at specific positions in the sentences and across the entire sentence. As such, the authors again concluded that automatic grammatical processing is not acquired by those who learn their second language later in life (while semantic processing is unaffected by age of acquisition).

Another pair of ERP studies (Hahne, 2001; Hahne & Friederici, 2001) suggests a similar yet perhaps more nuanced argument as concerns L2 syntactic processing. In these studies, phrase structure violations were employed in German (e.g., "Das Eis wurde im gegessen" - literal translation: "The ice cream was in the eaten") to determine whether Russian-German and Japanese-German late bilinguals would be sensitive to this type of anomaly. Akin to the study reported above (Weber-Fox & Neville, 1996), the late bilinguals in these studies did show a difference in the ERP trace to legal and illegal structures, as evidenced by P600, but unlike Weber-Fox and Neville (1996) these studies did not find a "delayed onset" of the P600 in bilinguals[6]. Two restrictions were nonetheless present. First, the difference in P600 as a function of sentence type was found only in advanced late bilinguals (mean formal learning 6 years; mean residency of 5 years), not in less-experienced L2 users (mean formal learning and residency of 2.5 years). Second, and most importantly for the authors' argument, while differences in the P600 were found in the advanced bilinguals as a function of sentence type, no differences were found in either of the late bilingual groups for an earlier left anterior negativity. Monolingual controls showed both effects. This pattern of results led the authors to suggest, in line with their previous monolingual work (Friederici, Hahne, & Mecklinger, 1996), that differences in automatic and more effortful syntactic processing can be indexed by these two components. The absence of an early effect in late bilinguals when encountering illegal structures in their L2 would suggest that they lack "automatic" processes present in native speakers.

Syntactic ambiguities : Variations in P600

The ERP studies cited up to now have all examined L2 processing for "anomalous" structures, that is sentences which contain either a semantic or syntactic anomaly in comparison to semantically/syntactically acceptable sentences, and or strings which contain only syntactic information compared to complete nonsense strings. Whether or not the ERP trace will reveal differences for anomaly ambiguity resolution is open to debate. In the one study that we are aware of that has used event related potentials to examine the processing of ambiguous structures in the L2 (Kotz, 1991), it would appear that perhaps there are indeed differences between "anomaly" and "ambiguity" processing.

In the study reported by Kotz (1991), the materials were the same as those used by Osterhout (1990; Osterhout & Holcomb, 1992). The materials played upon verb sub-categorisation information, as illustrated by 1 and 2, below:

> *1. The doctor agreed **to** see the patient **had** left the hospital.*
> *2. The doctor implored **to** see the patient **had** left the hospital.*

The sentence illustrated in 1 carries an intransitive verb (agree) whereas the sentence illustrated in 2 carries a transitive verb (implore) which requires either a direct object or

sentential complement. Given that both native and proficient non-native readers readily use this type of sub-categorization information (cf. Frenck-Mestre & Pynte, 1997), it is to be expected that at the preposition "to" the processing of sentence 1 (where "agree" is the main verb) will incur less difficulty than that of sentence 2 (where "implore" is the subordinate verb of a reduced relative clause followed by a main clause). This was born out in the ERP data for both monolingual controls and highly proficient Spanish-English bilinguals (mean age of acquisition of English = 5.3 years). Both groups showed a significantly larger P600 (time window 600 - 800 ms[7]) at the preposition "to" when reading sentences containing a transitive verb (as illustrated in 2) than an intransitive verb, (as illustrated in 1). No interaction with group (monolingual vs. bilingual) was observed. Moreover, at the subordinate verb "had", the inverse effect was found, whereby P600 was larger for sentences in which the first verb was intransitive and thus did not entail a subsequent main clause (example 1) than for those with a transitive verb where "had" provided the main verb (example 2). This obtained for both monolingual and bilingual readers.

The results of this ERP study show, in line with the eye-movement studies reported earlier in this chapter, that proficient L2 readers produce similar results to those obtained for native readers and that highly specific information, such as the type of construction most commonly associated with a particular verb class, is used by proficient bilinguals in their second language.

What to conclude as concerns L2 syntactic processing in late bilinguals?

In contrast to the ERP data reported for *semantic* anomaly detection in the second language, which has been found to be basically equivalent in the second and native language, data on *syntactic* anomaly detection show discrepancies between native and second language processing (Hahne, 2001; Hahne & Friederici, 2001; Sanders & Neville, 2003; Weber-Fox & Neville, 1996). Why this should be so, when eye-movement data has quite often shown that, provided sufficient proficiency, second language syntactic processing obeys the same principles as native language processing (Dussias, 2001; Frenck-Mestre, 1997; 2002; Frenck-Mestre & Pynte, 1997; Hoover & Dwivedi, 1998; Juffs & Harrington, 1996) is a matter worth contemplating.

As a possible explanation for the differences in results across eye-movement and ERP studies, I suggest that there are major differences in the scope of ERP studies on second language syntactic processing and that of the eye-movement studies presented in the first half of this chapter. First, bilingual ERP studies have by and large examined the processing of syntactic anomalies (with the exception of Kotz, 1991). Eye-movement studies on syntactic processing, both mono- and bilingual, are dominated by the study of syntactic ambiguities. Second, the main thrust of these ERP studies has been to test the "critical period hypothesis;" either direct cross-longitudinal comparisons have been made between "early" and "late" bilinguals as concerns syntactic anomaly detection or, within the "late" bilinguals, comparisons have been made with monolingual data as concerns semantic and syntactic anomaly detection. In the eye-movement studies we discussed, only the performance of "late" bilinguals was under scrutiny. Both experienced and beginning bilinguals' data was examined, but nonetheless for "late" bilinguals (i.e., those that learned their L2 after age 12, and in almost all cases in a scholastic setting). The debate still rages as to whether these "late" bilinguals can ever obtain the same level of automatic processing as native speakers (cf. Birdsong, 1999, for a recent discussion of the question), but such is beyond the scope of the present chapter.

Unlike the ERP studies of anomaly processing, the study of syntactic ambiguities has revealed quite coherent patterns across ERP and eye-movement studies. Both measures produce highly similar patterns for native and proficient non-native speakers. Moreover, there are parallels between the ERP data for anomaly processing and eye-movement data on ambiguity resolution. In both, it has been reported that with increasing L2 experience late bilinguals' performance resembles that of native readers to a greater or lesser degree. Note, however, that the ERP literature on the processing of syntactic anomalies unanimously finds late bilinguals to be lacking when it comes to "early" processing decisions in these subjects[8]. This is not the case in the eye-movement literature, which clearly reports very detailed and immediate use of grammatical information during parsing in the L2 for highly proficient late bilinguals.

It is my contention that to understand just where and why the data differ between eye-movements and event-related potentials, direct comparisons must be made between the same subjects and, most importantly, for the same type of processing. Resolving a syntactic ambiguity may well entail re-appraisal of a structure and "repair processes," however repair is indeed a possibility. This is not at all immediately apparent for illegal structures, such as have been used in the majority of ERP studies to date. What does the reader "do" when unable to resolve a phrase-structure violation? While the eye-movement studies we reported show considerable change in L2 syntactic ambiguity resolution with experience and near-native performance for the most highly skilled bilinguals, it is less evident that improvement would be found for the processing of illegal structures, such as those employed in the bilingual ERP studies.

Future research on second-language syntactic parsing is thus faced with an interesting new avenue. Comparisons across techniques (eye-movement, ERPs, and, lest we forget, fMRI) with comparable subject pools and linguistic materials should provide for clear advances in our understanding of this most intriguing topic.

NOTES

[1] Note that this principle can be transgressed in two specific cases : 1) when the direct object is a heavy NP, as illustrated by "The jury will reveal after lunch [the verdict over which they have been debating for almost three weeks.]" ; 2) when the direct object is a sentential complement, as illustrated by "The judge said on Monday [that he would refuse to reconsider the case.]

[2] In French, sentences such as those illustrated in parentheses are both equally licensed by the grammar ("Jean boit son café lentement" " Jean boit lentement son café").

[3] White (1991) also entertains the hypothesis that the effect observed in French readers of English may be due to differences across English and French as concerns verb raising, as suggested by Pollock (1989).

[4] Fodor (1999) as well as Bley-Vroman (1991) and MacWhinney (1997) argue rather strongly against the arguments put forward by White (1989a,b), who situates second language processing within the greater theory of Universal Grammar.

[5] It should be noted that the frequency of structures on its own is most likely not strong enough to reduce all ambiguity, as has clearly been outlined by MacDonald and colleagues (1994; 1997). Stronger constraints would be provided by the culmination of several factors (cf. MacRae et al., 1997).

[6] In the Hahne (2001) and Hahne and Friederici (2001) studies, the time window for the P600 ranged between 500 and 1200 ms. Otherwise stated, it was not broken down into several windows, as was the case for the Weber-Fox and Neville (1996) study. Note, nonetheless, that visual inspection of the ERP data, does not suggest an earlier onset of "P600" in the monolingual control group.

[7] An earlier time window, between 500 and 650 ms, revealed no differences as a function of structure, for either the monolingual controls or bilingual readers.

[8] It is well beyond the scope of this chapter to entertain the current disputes in the literature regarding the exact nature of the different ERP components observed during syntactic anomaly detection. The interested reader should note, however, that there is presently no clear consensus on this issue (cf. Friederici et al., 1996, 1997; Osterhout & Hagoort, 1999; Osterhout et al., 1996).

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