Modularity of L2 Sentence Processing: Prosody, Context, and Morphology in Relative Clause Ambiguity in English-French Interlanguage

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1. On the nature of second language sentence processing

1.1. Processing modularity

Fodor (1983) argued that the mind includes a module devoted to sentence processing that operates on the representations themselves, but crucially not on sentence-external information. Universal Grammar (UG) conceivably provides the contents of this universal, domain-specific processor, which is supplemented by a parameterized lexicon (Fodor, 2000; Schwartz, 1999). Crocker (1996) modeled such a processor, a universal parser, as constitutive of the theory of UG in the Principles and Parameters framework, augmented with a performance theory, the principle of incremental comprehension: "The Sentence Processor operates in such a way as to maximize comprehension of the sentence at each stage of processing" (p. 106). This principle requires immediate processing in each module as input is encountered. All modules operate concomitantly, each according to its principles of combination and in accordance with interface relations specified by UG. Speed is achieved by breaking down the large task into domain-dependent, autonomous, smaller processing tasks. Processing in each submodule is limited to a certain domain of grammar: phonology-prosody, semantics, phrase structure, thematic structure, and chain representations, *inter alia*—each assigning a partial grammatical representation following its own vocabulary and governed by interface relations as each input expression is identified (e.g., Crocker). Furthermore, sentence processing deals with ambiguity by following pre-designated routes, even if they result in garden paths (e.g., Crocker; Fodor & Inoue, 1998, 2000; Frazier, 1987; Frazier & Clifton, 1996; Frazier & Rayner, 1988).

According to the principle of incremental comprehension, any input must therefore receive a syntactic analysis in the syntactic modules, a prosodic analysis in the phonological module, and a semantic representation in the interpretive module—in the limits of the computations inherent in each module and interface. Focusing on phrase structure relations, Fodor and Inoue (2000) argued that the parser adopts whichever syntactic attachment is computed most rapidly and proposed the condition called attach quickly, which stipulates: "On receiving a word of the input sentence connect it to the current partial phrase marker as quickly as possible" (p. 23). Constituents are thus attached as they are encountered, and the resulting structure is verified against the grammar. Fodor and Inoue characterized this integration, which has no regard for eventual outcome, with the condition attach (anyway): "On receiving a word of the input sentence, connect it to the current partial phrase marker for the sentence wherever it least severely violates the grammar, subject to preference principles" (p. 26). Therefore, at each step in processing, the parser constructs the most economical syntactic representation that permits a full interpretation of the input so far. Parsing strategies such as minimal attachment (Frazier, 1979), right association (Kimball, 1973), late closure (Frazier & Fodor, 1978), active filler (Clifton & Frazier, 1989; Stowe, 1986), theta attachment (Pritchett, 1992), and so forth, derive from this design.

1.2. Second language processing and modularity

A body of research argues that aspects of second language (L2) differences between native speakers (NSs) and nonnative speakers (NNSs) are a reflex of a universal processing mechanism devoted to language (Dekydtspotter, 2001; Dekydtspotter, Donaldson, Edmonds, Fultz, & Petrush, 2008; Frenck-Mestre, 1997, 2002, 2005; Juffs, 1998a, 1998b, 2006; Juffs & Harrington, 1995, 1996).

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Indeed, such research shows that L2 processing is guided by a reflex to resolve dependencies as quickly as possible, *per* the active filler strategy, rather than delay until sufficient information has been adduced. Juffs and Harrington hypothesized that the sentence processing mechanisms explained NNSs' processing difficulties with subject (1a) versus object extractions (1b) and their sensitivity to garden paths (see also Juffs, 1998a). NNSs' rejection of subject (1a) versus object extractions (1b) was accompanied by increased reading times (RTs) after the verb *say* in the processing of (1a).

(1) a. Who did Ann say likes her friend?
b. Who did Ann say her friend likes?

They reasoned that a structural reflex guides the integration of the filler with the verb *say*—although this is quickly undone before construing it with *likes*. NNSs, unlike NSs, experienced difficulty recovering from these misanalyses presumably under an increased processing load (see also Williams, Möbius, & Kim, 2001).

The hypothesis that L2 processing obeys a reflex to structure the input immediately, subject to economy principles, is best supported by Lieberman, Aoshima, and Philips (2006) in the processing of *wh*-extractions in English-speaking learners' processing of Japanese. In Japanese, a *wh*-expression in situ may be construed with a matrix-clause Q-marker as in (2a) or with an embedded-clause Q-marker as in (2b). The embedded-clause interrogative complementizer *ka* in (2b*)* was read significantly faster than the embedded-clause declarative complementizer *to* in (2a) (Miyamoto & Takahashi, 2002). This clause-typing effect, which is a counterpart to the active filler strategy, given the grammar of Japanese, was analyzed as a reflex to seek a scope marker quickly.

(2) a. *Senmu-ga donna-pasokon-wo tukatteiru-to kakaricyoo-ga itta-no?*
director-NOM what kind computer-ACC using-is-COMP supervisor-NOM said-QM
"What kind of computer did the supervisor say that the director is using?"
b. *Senmu-ga donna-pasokon-wo tukatteiru-ka kakaricyoo-ga itta.*
director-NOM what kind computer-ACC using-is-QM supervisor-NOM said
"The supervisor said what kind of computer the director is using."

Similarly, given an incomplete sentence as in (3), in which the *wh*-expression could receive either embedded- or matrix-clause scope, NSs typically complete the sentence with the embedded-clause construal, establishing a dependency with a Q-marker quickly.

(3) *tannin-wa sisyo-ga tosyositu-de donno sinnyusei-ni…*
class-teacher-TOP librarian-NOM library-at which new student-DAT…

English learners of Japanese fixed the scope of the *wh*-expression in the incomplete sentence in (3) as soon as possible, despite the fact that, in English, an in situ *wh*-expression (in echo questions) takes matrix-clause scope. The relation between the *wh*-expression and the Q-marker is purely formal, which suggests that L2 sentence processing is guided by a structural reflex to resolve dependencies quickly, although the form that this reflex takes depends on the representations undergoing processing.

Although L2 sentence processing appears to be channeled by a general mental system devoted to language, learners have been observed to be slower and to often fail to revise in the limits of resources. Indeed, as a function of differences in global processing speed, due in part to lexical access and retrieval (Favreau & Segalowitz, 1983), time courses on the same task may reflect different moments of processing for NSs and NNSs. Target deviant time courses may result from (a) (first language [L1]-derived) nontarget Interlanguage grammars at various levels or (b) slower retrieval of representations, triggering less ability to revise in the limits of fixed resources. However, as Juffs (2006) and Dekydtspotter, Schwartz, and Sprouse (2006) noted, the fact that native and nonnative processing profiles differ does not necessarily mean that they differ fundamentally.

This position is opposed by a body of research that advances the shallow structures hypothesis, according to which L2 syntactic representations are not of a type that allows speedy deployment, and, as a result, learners construct shallow representations reliant on lexical-thematic and contextual-pragmatic information (Clahsen & Felser, 2006a, 2006b; Felser & Roberts, 2007; Felser, Roberts, Gross, & Marinis, 2003; Marinis, Roberts, Felser, & Clahsen, 2005; Papadopoulou, 2005; Papadopoulou & Clahsen, 2003). These researchers would deny that the effects considered above are

the hallmark of a domain-specific module dedicated to language. To arbitrate between these two hypotheses, two types of evidence have been called upon. The first type comes from proof, or lack thereof, for abstract syntactic representations (e.g., traces, intermediate traces). For L2 learners, no consensus has yet been reached, with some authors claiming that traces are not posited in L2 processing (Felser & Roberts, 2007; Marinis et al., 2005), whereas others have provided evidence suggestive of such traces (Dekydtspotter, Kim, et al., 2008; Dekydtspotter, Miller, Chang, Kim, & Schafer, to appear). As shown by Dekydtspotter et al. (2006), methodological differences are undoubtedly at least in part responsible for these results. The second type of evidence stems from processing in independent modules, assuming informational encapsulation (Fodor, 1983, 2000). Proponents of the shallow structure hypothesis have argued that L2 processing differs fundamentally from L1 processing, insofar as learners rely on the direct use of context and thematic information in guiding the parse in relative clause (RC) attachment (Felser et al., 2003; Marinis et al., 2005; Papadopoulou & Clahsen, 2003). This directly contradicts the assumption of an informationally encapsulated processing module that operates on the basis of the local structure of representations alone. The current project examines the role of modular processing considering the role of computational load in the development of RC processing. The first study (Dekydtspotter, Donaldson, et al., 2008) examined the sensitivity of learners of French to manipulations in prosody in the interpretation of ambiguous RCs as well as the role played by prosody, syntax, and context in the processing of such constructions. The second study complements the first in the area of prosody and examined the importance of morphosyntactic computations in the online resolution of ambiguous RCs.

2. RCs: A processing problem

2.1. The processing of RCs and crosslinguistic differences

The attachment of ambiguous RCs, such as in (4) and (5), has been the focus of a large literature.

(4) Nous adorons le secrétaire du psychologue qui se promène.
(5) We adore the secretary of the psychologist who takes a walk.

Although the reflex to minimize structure during processing would predict that low attachment (i.e., interpretation of the RC as modifying *psychologue*, the second noun phrase or NP2) as opposed to high attachment (i.e., interpretation of the RC as modifying *secrétaire*, the NP1), considerable crosslinguistic variation has been documented. Specifically, NSs of French appear to generally favor high attachment of RCs (Baccino, De Vincenzi, & Job, 2000; Frenck-Mestre, 1997; Frenck-Mestre & Pynte, 2000; Zagar, Pynte, & Rativeau, 1997), whereas NSs of English generally prefer low attachment of RCs (e.g., Fodor, 2002).

This contrast between English and French suggests distinct processing strategies. Several explanations for variation in RC attachment have been put forward in L1 processing. In an experience-based approach, Cuetos and Mitchell (1988) argued for attunement of the parser (i.e., a mechanism that allows input to be processed) to frequencies in the input: They proposed that the parser tracks the relative number of unambiguous attachments in the input and follows these tendencies. Assuming a parametrizable parser in which various strategies compete, Gibson, Pearlmutter, Canseco-Gonzalez, and Hickock (1996) proposed a structural trigger that determines the relative strength of distinct parser operations. In a [+ verb-raising] language like French, a strategy of predicate proximity, by which the RC attaches directly to the argument of the verb (i.e., high attachment), takes precedence over the general recency strategy of attaching to the most recently processed constituent (i.e., low attachment). In a [- verb-raising] language like English, the general recency strategy is followed: The RC attaches to the most recently processed expression.

However, Fodor (1998, 2002) noted that the preference for high attachment of RCs in languages like French seems to be a lone exception to structure minimization. Indeed, across languages and constructions, the parser generally avoids generating more structure than necessary at each stage of processing, in line with principles such as right association (Kimball, 1973) and minimal attachment (Frazier, 1979). The postulation of construction-specific processing strategies seems incompatible with the general character of syntactic parsing. Fodor proposed that differences in default prosody result in different RC attachment preferences. High attachment is favored when the RC is its own major prosodic unit, whereas low attachment is favored when the RC is in the same major prosodic unit as

preceding material (in this case, the second noun or N2). In other words, prosodic requirements for French RCs are the source of the preference for high attachment of RCs. Jun (2003) provided evidence in support of Fodor's proposal with production tasks.

Thus, according to Fodor's (1998, 2002) prosodic hypothesis, the processing of RCs in French as in English involves structure minimization. In English, the RC preferentially falls under the prosodic constituent associated with the N2 converging with low attachment in syntax. In French, however, the RC preferentially constitutes its own prosodic constituent, following the pattern of right-branching complements, inducing a revision from low attachment to high attachment in syntax. In short, prosodic differences between English and French explain why (everything else being equal) RCs generally tend to be construed as modifying NP2 in English and NP1 in French.

This led Dekydtspotter, Donaldson, et al. (2008) to advance a research program that attempts to uncover whether English-French RC attachment exhibits asymmetries that reveal distinct grammatical operations, each restricted to their own domains, as well as what role may be played by processing load and computational complexity in different modules in explaining aspects of L2 behavior.

2.2. The processing of RCs in a L2

A current body of research, including notably proponents of the shallow structure hypothesis, has argued that L2 processing of RC attachment ambiguity is typically *unlike* that of NSs, even in advanced L2 learners. Thus, in their investigation of the processing of temporarily ambiguous RCs by advanced learners of Greek with German or Russian as their L1, Papadopoulou and Clahsen (2003) did not find an attachment preference in the genitive condition on a scalar acceptability judgment task; the learners also failed to produce RT asymmetries on a self-paced reading task. Greek NSs, however, produced evidence of favored NP1 attachment in acceptability ratings and in RTs. An example of the stimuli used is provided in (6). Gender agreement on the past participle disambiguated between attachment to NP1 or NP2, and the second noun occurred either after the genitive preposition *tis* or after the thematic preposition *me* "with."

(6) *O kirios idhe/ton psihiatro tis ithopiu (ton psihiatro me tin ithopio) /pu itan/kasthismen-os (-i)/ston kanape.*
"The man saw/the psychiatrist-MASC of the actress (the psychiatrist with the actress)/who was /sitting-MASC (-FEM) on the sofa."

With the thematic preposition, however, both NSs and NNSs preferred low attachment to NP2. Additionally, RTs were longer when NP1 attachment was forced in this condition. Papadopoulou and Clahsen reasoned that L2 learners relied heavily on lexical-thematic information but not on pure phrase structure information. They proposed that L2 learners delayed attachment to seek other information with the potential to resolve the structural ambiguity, whereas NSs implemented specialized structural strategies. Similar results with a similar design in which the number marking on the auxiliary verb disambiguated the attachment were found for advanced German and Greek learners of English in Felser et al. (2003). In their discussion of these results, Felser et al. concurred with Papadopoulou and Clahsen's conclusions—namely, that L2 processing is not based on phrase structure information.

Dussias (2001, 2003) examined RC attachment preferences of Spanish and English monolinguals versus late English and Spanish dominant bilinguals (in each group, respondents had 11 years of study and functioned in an academic environment). The instrument included an offline interpretation questionnaire in English and Spanish in which an ambiguous sentence was followed by a question and two answers and also a RT experiment in Spanish for which the critical items contained complex NPs joined by the genitive preposition *de* and modified by a temporarily ambiguous RC; the intended attachment was eventually disambiguated by a contextually disambiguating segment using natural gender, as in (7). In each example, the RC required a feminine head noun, which occurred in first or second position of the complex NP. As opposed to the stimuli for the RT experiment, questionnaire items simply lacked the last disambiguating segment.

(7) *El perro mordió/[(al cuñado/a la cuñada) (de la maestra /del maestro)]/que vivió en Chile /con su esposo.*
"The dog bit / [(the brother-in-law/sister-in law) (of the teacher-FEM/MASC)]/ who lived in Chile/with her husband."

Questionnaire results showed that Spanish monolinguals strongly favored high attachment, whereas English monolinguals strongly favored low attachment. Both bilingual groups were statistically different from Spanish monolinguals and not statistically different from each other on the Spanish questionnaire task. More specifically, on the Spanish task, both groups of bilinguals selected significantly fewer high attachments than Spanish monolinguals. On the English questionnaire task, the bilinguals were not statistically different from the English control group or from each other. In the self-paced reading task, Spanish monolinguals read the last segment faster when the RC modified NP1 than with NP2. A RT asymmetry in the opposite direction was found among the Spanish-English learners: These participants showed faster RTs on the last segment when the RC was interpreted as a modifier of the N2. On the basis of this evidence, Papadopoulou (2005) concluded that NNSs must rely on lexical-thematic information, context, and possibly defaults such as late closure, and that they do not immediately deploy a structural mechanism as do NSs.

Large differences between L1 and L2 sentence processing are not the only pattern found. Frenck-Mestre (2002) reported eye-movement studies of two groups of university-level English-French learners studying in France. The first group of NNSs had an average of 1 year of residency in France, whereas the second group had on average 5 years of residency. Spanish-French learners were also compared to the English-French learners to examine the effect of the native language on L2 sentence processing (NSs of Spanish generally favor NP1 attachment; see Fodor, 2002). A group of French NSs was tested to allow learner-native comparisons. Respondents read sentences as in (8) in which verbal agreement disambiguated the locus of RC attachment.

(8) *Jean a vu [la gardienne des filles/les filles de la gardienne] qui revient de Paris.*
"Jean saw [the nanny of the girls/the girls of the nanny] who comes back from Paris."

For Spanish-French learners, first-pass gaze durations on the verb were longer when it agreed with the N2. A similar asymmetry was produced by native French readers. English-French learners with just 1 year of residency in France produced the opposite bias: Longer first-pass gaze durations were produced on the disambiguating verb when it agreed with the first noun (N1). The group with a mean of 5 years of residency, however, produced an asymmetry in gaze duration that reflected the development of a French-like bias for attachment to NP1. Pointing to effects of the L1 in the contrast between English-French and Spanish-French learners and to the target language-like performance of the skilled English-French learners, Frenck-Mestre (2002) argued for similar processing by NSs and NNSs, despite the general slowness that persisted even in highly skilled L2 readers. These results are unexpected under the shallow structures hypothesis, which excludes structural biases and L1 effects.

3. RC ambiguity resolution in the modules

The hypothesis that L2 sentence processing is constrained by a modular universal parser (*pace* the parameterized lexicon) dedicated to language makes specific predictions. A body of research that reports similarities with native processing in adherence to general principles of economy manifested in similar ways is highly suggestive. However, in the case of RC attachment disambiguation in a L2, the data have not been well-behaved, with learners generally failing to show the same propensities as NSs on many tasks. Still, as Dekydtspotter, Donaldson, et al. (2008) pointed out, the contrast between thematic and non-thematic prepositions reported in processing of RC attachment ambiguity resolution in L2 processing is also well in keeping with what is generally known about sentence processing. The strength of attachment preferences of RCs to NP1 or NP2 in the context of a non-thematic genitive preposition is affected by many factors such as RC-length, definiteness, animacy, frequency of the noun and prosody; however, thematic prepositions robustly favor NP2 attachment. The pattern of the break-downs suffered by NNSs seems to reflect the robustness of RC attachment preferences crosslinguistically. Thus nonnative prosody under various conditions can be expected to influence the attachment preferences of learners, as can the inherent computational costs associated with certain structures.

Because the task of processing is broken down into subtasks—each module autonomously processing according to its vocabulary and operations defined over them—L2 sentence processing should also bear the hallmark of the organization of the sentence processor. Thus, Fodor (1998) argued that the influence of prosody during processing is best exemplified by the effect of RC-length on RC attachment (9), a phenomenon that can be explained in terms of a desideratum of prosodic balance. Fodor proposed that prosodic balance follows from a tendency towards bisection as a means of reconciling the flatter prosodic representation with binary-branching syntactic structure. Given the search for prosodic balance, the effect of RC length is readily expressed in terms of the reanalysis of abutting boundaries of prosodic constituents. Thus, a short RC would favor a reanalysis as in (10), whereas a long RC would favor reanalysis as in (11).

(9) *Nous adorons le secrétaire du psychologue qui se promène (au centre ville)*.
"We adore the secretary of the psychologist who takes a walk (downtown)."

(10) [$_{Utt}$ [$_{IntPhr}$ Nous adorons le secrétaire] [$_{IntPhr}$ du psychologue qui se promène]]
[$_{Utt}$ [$_{IntPhr}$ We adore the secretary] [$_{IntPhr}$ of the psychologist who takes a walk]]

(11) [$_{Utt}$ ... [$_{IntPhr}$ le secrétaire du psychologue] [$_{IntPhr}$ qui se promène au centre ville]]
[$_{Utt\ ...}$ [$_{IntPhr}$ the secretary of the psychologist] [$_{IntPhr}$ who takes a walk downtown]]

At the interface with syntax, the prosodic structure in (10) best fits with a syntactic structure in which the RC is attached to NP2, whereas the prosodic structure in (11) best matches a syntactic structure in which the RC is attached to NP1. Crucially, syntactic and prosodic computations are blind to each other and to context.

Thus, general requirements ensuring computational efficacy can be expected to bear the hallmark of each submodule and effects of computation load can also be expected to bear different signatures revealing of subareas of grammar. The central research question is therefore whether there is evidence of diverse reflexes suggestive of distinct computations in various modules to be integrated at the interface. Dekydtspotter, Donaldson, et al. (2008) focused on evidence for distinct computations and their interfaces. We focused here on computational load in the modules in light of new prosodic and morphological data.

4. Study 1: Prosody, context, and syntax

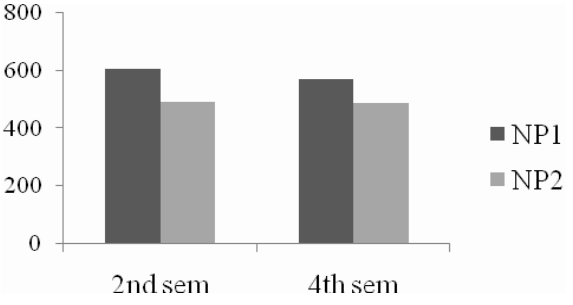
Dekydtspotter, Donaldson, et al. (2008) sought to determine whether learners carried out prosodic computations in the resolution of ambiguous RC attachment in silent reading and whether they were sensitive to RC length and intonation. They then considered whether knowledge of context can directly influence attachment preferences. The central issue is whether L2 processing conforms to this architecture. The study had second- and fourth-semester English learners of L2 French complete three tasks. Tasks 1 and 2 contained sentences with fully ambiguous RCs as illustrated in (12c) that were either read silently (RC length manipulated as in Task 1) or presented aurally (RC length and intonation contour manipulated as in Task 2). A general NP1 attachment preference was found for all learners, which was qualified by RC length. However, second-semester learners showed no sensitivity to intonation contour and only a subset of fourth-semester learners were found to exhibit such sensitivity, which suggests a partial effect of prosodic information.

Task 3 was a self-paced moving window experiment. It was administered approximately 1 week after Tasks 1 and 2. Respondents sat at Macintosh computers running Psyscope software (Cohen, MacWhinney, Flatt, & Provost, 1993). They were first presented with a context in English that unambiguously required either a construal of the RC with NP1 or with NP2, followed by a noncumulative moving-window presentation of sentences with long RCs, as illustrated in (12). Slashes are used in these examples to show the segmentation of the test items into seven sections. Thus, fully ambiguous RCs as in (12c) were paired with disambiguating contexts as in (12a) and (12b) for NP1 and NP2 attachment, respectively. Respondents saw only one segment at a time; a new segment was called up by the respondent's press of a button, and the computer measured time elapsed between button presses. Following this presentation, respondents were asked the question "Is this a correct description?" They then pressed buttons to answer *yes*, *no*, or *cannot tell*.

(12) a. NP1 attachment
Jeanne loves to throw parties and invite guests with different interests. Jeanne has found out that Dr. Ratiche, the dentist of her doctor, cooks everyday and always brings in treats for his patients. Jeanne's doctor, along with all the other dentists she knows, has no special culinary talents. So, Jeanne decides to invite Dr. Ratiche to her next party.
b. NP2 attachment
Jeanne loves to throw parties and invite guests with different interests. At her next dental appointment, Jeanne learns that her dentist has many patients who are doctors and that one of these doctors, Dr. Toubib, cooks every day. Although her dentist is hopelessly untalented when it comes to cuisine, Jeanne decides to invite her dentist to her next party, in the hopes that the dentist will bring his talented patient, the doctor Dr. Toubib.
c. Experimental item
Jeanne / invite / le dentiste / du docteur / qui cuisine / tous les jours.
"Jeanne invites the dentist of the doctor who cooks every day"

The task included 20 experimental sentences and 20 fillers, and participants generally completed the task in less than 30 min. All test sentences were true statements based on the contexts. However, depending on the attachment, these statements could become false. All fillers contained RCs that unambiguously attached to a simple NP, and half of the fillers also contained a complex NP somewhere in the sentence. Mean RTs for all segments on each of the two conditions were calculated. For each of the two contextual conditions, RTs more than two standard deviations beyond the means were removed. Only RTs for which a *yes* response was given contributed to measurements, because only *yes* responses are informative of the interpretation assigned. Twenty experimental items crossed with two contextual conditions provided 40 items for analysis. One item was removed from the analysis; it was rejected in both conditions because a problem shared by both contexts resulted in substantially fewer acceptance rates for this item. Figure 1 presents the RTs (in ms) on the verb segment for each type of attachment by group.

Figure 1: RTs on the Verb Segment



As can be seen in Figure 1, second- and fourth-semester learners of French showed shorter RTs on the RC verb in NP2 attachment contexts, with no significant group difference. This difference was significant by subject, $t_1(63) = 4.574$, $p < .0005$, and by item analysis, $t_2(18) = 4.340$, $p < .0005$. The effect found in the RT data is consistent with a reflex to parse input quickly, attaching the RC to the closest NP (i.e., NP2). Thus, the context did not play a direct role in assigning a parse. In fact, fourth-semester learners produced more *yes* responses in NP1 contexts with 64% of positive responses versus 36% of responses in NP2 contexts, $t(44) = 5.700$, $p < .0005$. This difference between NP2 attachment preferences in processing and NP1 attachment in final judgments argues for autonomous syntactic processing.

5. Study 2: Prosody, morphology, and syntax

5.1. Task 1: Prosody and Length

The first part of the task is a replication of Dekydtspotter, Donaldson, et al. (2008). The paper-and-pencil reading task consisted of 40 items, presented in a booklet, in which RC length was

manipulated: Twenty critical items contained long RCs and 20 contained short RCs. There were 10 fillers that involved two potential noun antecedents and a RC or a genitive construction. For each item, a question about which noun was modified by the RC followed. Two possible answers (N1 and N2), presented in counterbalanced order, were provided along with the option *cannot tell*. An example item, with a short RC, is provided in (13).

(13) *Il adore le boucher du docteur qui grossit.*
"He adores the butcher of the doctor who gains weight."
Qui grossit?
"Who gains weight?"
(a) le boucher (b) le docteur (c) Cannot tell

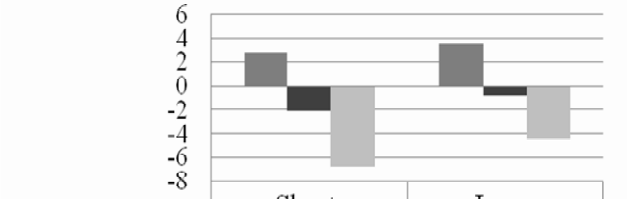
Participants were asked to indicate the answer that came to them most readily by circling one of the proposed answers: (a) or (b). They were instructed to select the option *cannot tell* if they could not make any determination. Participants were further instructed to act as quickly as possible, to follow immediate intuitions, not to second guess themselves, and not to go back. The order in which the N1 and the N2 appeared in the answer line (i.e., whether response [a] or [b] contained the N1 or the N2), was randomly assigned for each item.

The participants were 63 intermediate English learners of French in their fourth semester of study. There were also 13 French advanced learners (with 1 year of residence in France). A control group of 13 NSs currently residing in the US also completed this task.

If Fodor's (1998, 2002) proposal, which states that prosodic requirements are the source of the preference for high attachment of RCs in French, is correct, we would expect readers to respond to RCs of different lengths in distinct manners. Fodor suggested that French RCs prefer to project their own prosodic constituent, following the pattern of right-branching complements. This segmentation leads to a revision from low to high attachment (i.e., to NP1). Such a preference is expected to be overcome more easily with short RCs than with long ones (see Pynte & Colonna, 2000, for evidence of sensitivity to prosodic weight with NSs of French). We therefore hypothesize that a low attachment tendency with short RCs should be inhibited by lengthening the RCs.

The analysis was conducted on the differences in selections of N1 versus N2 answers. For each participant, we subtracted the number of N2 selections from the number of N1 selections in both conditions, as illustrated in Figure 2. Thus, positive scores indicate a preference for NP1 attachment, whereas negative scores represent a tendency to attach the RC to the NP2. *T* tests were run on the difference between N1 and N2 answers by RC length. The difference was found to be theoretically significant for the fourth-semester learners, $t(62) = 1.926$, $p = .059$. For the advanced learners, the difference was not significant $t(12) = 1.008$, $p = .33$, but it was significant for the NS group, $t(12) = 3.094$, $p < .01$.

Figure 2: N1 Versus N2 Answers



	Short	Long
4th semester	2.76	3.52
Advanced	-2.15	-0.85
NSs	-6.77	-4.46

We note that on this stimulus the NSs showed both an effect of length and a preference consistent with minimal attachment, exhibiting a reflex to minimize structure. Reflexes of structure minimization have also been found in native French RC processing (Baccino et al., 2000; Pynte & Colonna, 2000),

despite the general preference for NP1 attachment. The French speakers were, however, tested in the US and these results therefore go in the same direction as Dussias' (2001) study of bilinguals versus monolingual speakers of Spanish.

5.2. Task 2: Prosody and Length

In this task, participants were presented only aurally with sentences identical to those in Task 1. Participants were to respond to the same comprehension questions as those in Task 1, and the order in which the N1 and the N2 appeared in the response line was randomly assigned. Both RC length and intonation contour were manipulated: Forty experimental items and 40 fillers were created. Half of the experimental items contained long RCs and half contained short RCs, and each individual test item was recorded with two different prosodic contours: In (14a), the RC forms its own prosodic constituent, schematically represented as [N1 N2] [RC], whereas in (14b), the RC forms a prosodic unit with the N2, represented as N1] [N2 RC]. Given the lack of prosodic break, we expect that NP2 attachment will be favored more in the case of (14b) than in the case of (14a).

(14) a. [N1 N2] [RC]
Nous adorons [le secrétaire du psychologue] [qui se promène].
"We adore the secretary of the psychologist who takes a walk."
b. N1] [N2 RC]
[Nous adorons le secrétaire] [du psychologue qui se promène].
"We adore the secretary of the psychologist who takes a walk."

According to Jun and Fougeron (2002), prosodic units in French are punctuated with a boundary tone on the last tone-bearing syllable. Thus, when the N1 ends the prosodic constituent, it bears a primary rising tone, whereas when the N2 ends the prosodic constituent, the tone occurs on the last full syllable of this noun. Inspection of the aural stimuli revealed the tone placement pattern described by Jun and Fougeron. Additional inspection of the auditory signal showed that a secondary high tone on the relative pronoun was higher when the RC formed an independent prosodic constituent than when the RC was prosodically grouped with the N2. Finally, pause duration was found to vary with respect to intonation contour, with significantly longer pauses being found at the end of prosodic constituents. As it was not our intent to investigate to which phonetic cues learners might be sensitive, the signal was not manipulated after recording.

The participants received Task 2 in the same booklet as Task 1, and the listening task was completed after the silent reading task. Three different randomizations of each task were prepared. The session was held in a language laboratory in which participants sat at individual computers. Participants controlled the speed at which they completed the tasks.

As for the previous task, and as illustrated in Table 1, the number of N2 answers was subtracted from the number of N1 answers, so that positive numbers indicate a NP1 attachment preference whereas negative numbers identify a NP2 attachment preference. A repeated-measures ANOVA with prosody and length as within-subject factors and group as between-subject factor revealed a main effect of length, $F(1, 86) = 14.224$, $p < .0005$, and prosody, $F(1, 86) = 86.541$, $p < .0005$, as well as an interaction between intonation contour and group, $F(2, 86) = 25.955$, $p < .0005$, as well as a marginal interaction of length and group, $F(2, 86) = 2.957$, $p = .057$, and of length, intonation contour, and group, $F(2, 86) = 2{,}752$, $p = .069$. There was also a main effect of group, $F(2, 86) = 27.950$, $p < .01$.

Table 1: N1 Versus N2 Answers by Prosody and Length and by Group

	Fourth semester (n = 63)		Advanced (n = 13)		NSs (n = 13)	
Length	[N1 N2] [RC]	N1] [N2 RC]	[N1 N2] [RC]	N1] [N2 RC]	[N1 N2] [RC]	N1] [N2 RC]
Short	2.7937	1.6508	.2308	-4.8462	-2.6154	-6.8462
Long	2.3651	2.6349	1.1538	-3.6154	-.1538	-6.3077

Given these effects of group, we examined the results for each group. An ANOVA indicated that fourth-semester learners produced a crucial interaction of length by intonation contour, $F(2, 86) = 5.693$, $p < .05$. Planned t tests revealed that, for the fourth-semester learners, the prosody N1] [N2 RC] resulted in more N1 answers with long versus short RCs, $t(62) = 2.426$, $p < .05$. Additionally, for this learner group, short RCs depressed the number of N1 answers with this same prosodic contour, $t(62) = 2.972$, $p < .005$. For advanced learners, the ANOVA revealed main effects of intonation contour, $F(1, 12) = 35.864$, $p < .0005$, and a marginal effect of length, $F(1, 12) = 4.265$, $p < .061$. T tests revealed that short RCs led to fewer N1 answers with the N1] [N2 RC] prosody, $t(12) = 4.794$, $p < .0005$, and so did long RCs, $t(12) = 4.147$, $p < .005$. NSs showed a similar pattern: The ANOVA revealed main effects of intonation contour, $F(1, 12) = 33.440$, $p < .0005$, and length, $F(1, 12) = 13.00$, $p < .005$. T tests revealed fewer N1 answers with the N1] [N2 RC] prosody for short RCs, $t(12) = 4.282$, $p < .005$, and for long RCs, $t(12) = 5.359$, $p < .0005$. It is interesting to note that, for the NSs, the [N1 N2] [RC] prosodic contour led to more N1 answers with long RCs, $t(12) = 2.606$, $p < .05$.

5.3. Task 3: Morphology and syntax

This computerized timed reading task was administered approximately 1 week after Tasks 1 and 2. Participants sat at Macintosh computers running Psyscope software (Cohen et al., 1993). Presented in a self-paced moving window presentation, this task consisted of 20 experimental quadruples—a sample quadruple is provided in (15)—in a Latin square design crossing attachment (NP1 or NP2) and number marking (singular or plural). The design of the items was modeled after an experiment reported on in Frenck-Mestre (2002), for which she used an eye-tracking methodology. The verb disambiguated the attachment of the RC. Participants read the sentences (only one per quadruple) in five segments and indicated whether the sentence was acceptable. Participants saw only one section at a time; a new section was called up by the respondent's press of a button, and the computer measured time elapsed between button presses. Following this presentation, participants were asked the question "Is this a correct description?" They then pressed buttons to answer *yes*, *no*, or *cannot tell*.

(15) *Aline téléphone / aux filles / de la gardienne / qui revient / ce soir. /*
Aline téléphone / aux filles / de la gardienne / qui reviennent / ce soir. /
Aline téléphone / à la gardienne / des filles / qui revient / ce soir. /
Aline téléphone / à la gardienne / des filles / qui reviennent / ce soir. /
"Jean saw [the nanny of the girls/the girls of the nanny] who [comes/come back] from Paris."

This task was completed by 37 intermediate learners in their fourth semester, 15 advanced learners of French (with 1 year of residence in France), and a control group of 14 NSs currently residing in the US. These participants had completed the previous two tasks; however, the numbers are slightly different due to technical difficulties. The acceptance rates were computed, and the RTs on the disambiguating segment (i.e., the verb of the RC) were examined. RTs more than two standard deviations beyond the means were removed from analysis. A repeated-measures ANOVA with number marking and attachment as within-subject factors and group as between-subject factor was conducted.

The results for the acceptance rates are presented in Figure 3. As can be seen, fourth-semester and advanced learners seem to accept all sentences at fairly high rates.

Figure 3: Acceptance Rates

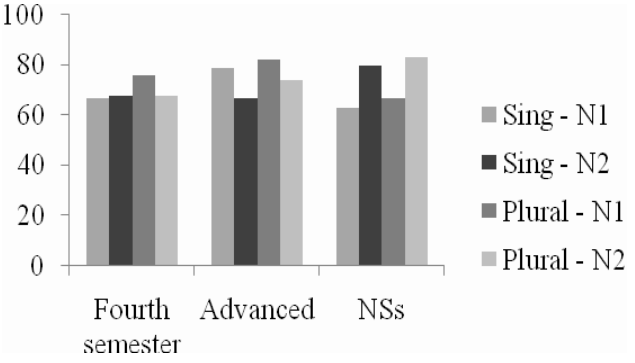
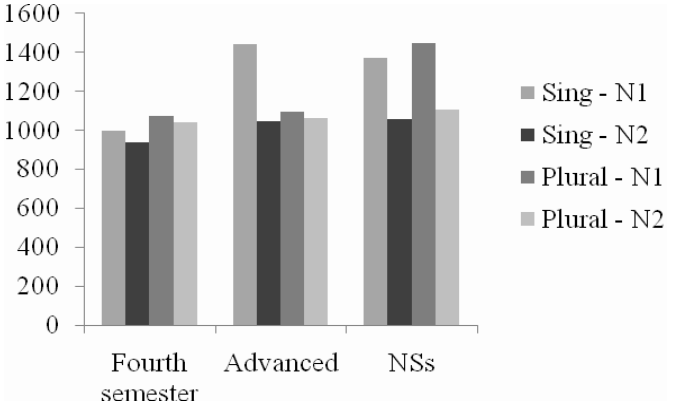


Table 2 provides the detailed results of the RT data on the disambiguating verb, and Figure 4 provides a schematic view of these results. Planned *t* tests were performed and revealed no significant differences in the RT profiles of fourth-semester learners. For advanced learners, on singular verbs only, the agreement with NP2 yielded significantly faster RTs, $t(14) = 4.965$, $p < .0005$. For NSs, the agreement with NP2 yielded faster RTs for both singular, $t(13) = 1.985$, $p = .069$, and plural verbs, $t(13) = 2.675$, $p < .05$.

Table 2: RTs on the Disambiguating Segment (ms)

	Fourth semester ($n = 37$)		Advanced ($n = 15$)		NSs ($n = 14$)	
Number	NP1	NP2	NP1	NP2	NP1	NP2
Singular	1000	938	1443	1046	1372	1060
	(296)	(236)	(341)	(257)	(742)	(350)
Plural	1073	1044	1093	1065	1448	1108
	(306)	(256)	(355)	(200)	(551)	(311)

Figure 4: RTs on the Verb by Group



6. Discussion: RC attachments in L2 French and computational complexity

Dekydtspotter, Donaldson, et al. (2008) showed that intermediate English-speaking learners of French were sensitive to the length of the RC in specific ways: Longer RCs induced more L1 attachments than short RCs. There was also an effect of intonation contours in some intermediate learners of French: This was suggestive of a prosodic reflex.

The current study also provided very solid evidence of sensitivity to RC length by intermediate learners during silent reading, which confirms the results reported on earlier. A general NP1-attachment preference was observed in intermediate learners, which does not follow from English preferences. The advanced learners show a profile in which NP2 attachment preference is in evidence, which is also mitigated by RC length. The performance of French NSs on this task was similar to the advanced learners, if slightly more pronounced. For all groups, RC length had a similar expected effect. The current study unequivocally showed that attachment decisions made by fourth-semester learners are also sensitive to prosodic information qualified by RC length: The general NP1 attachment preference is severely constrained by the N1] [N2 RC] intonation contour with short RCs since both prosodic balance and actual contour push for the same representation, which in turn best matches low attachment in syntax. For advanced learners, a distinct effect of intonation contour mitigated by length was also observed. Its character is slightly different because the N1] [N2 RC] intonation contour induces a solid NP2 construal; whereas RC length has a strong effect in predicting the strength of the N1 preference in the [N1 N2] [RC] intonation contour. This is presumably because, although this contour suggests a NP1 construal for Gricean reasons by not specifying NP2, it is in principle compatible with either construal. The major factor in development is the fact that intermediate learners show a very robust N1 preference across the board (that is of course mitigated by prosody and length), whereas advanced learners have lost this across-the-board N1 preference, whereby their results reflect the effects of prosody more fully. These are *prima facie* evidence of a prosodic reflex in RC attachment in English-speaking learners of French, much as there seems to be a syntactic reflex.

Effects of prosodic information (intonation contour and prosodic weight) suggest that the strength of the NP1 attachment preference in intermediate learners finds an explanation within the prosodic component. The robustness of these findings then raises the question of what factor could bring about a prosodically driven NP1 attachment preference: Computational complexity in interaction with the prosodic module provides a potential explanation. Svets, Desmet, Hambrick, and Ferreira (2007), investigating effects of working memory (WM) limitations on (large numbers of) NSs of American English and NSs of Dutch, found that lower WM individuals tended to accept more NP1 attachment than higher WM individuals. These authors explained that this effect results from a segmentation strategy grouping words in smaller units during reading in the face of computational complexity. Such segmentation favors NP1 attachment at the interface between prosody and syntax. On this view, the behavior of the intermediate English learners of French is suggestive of the potential role of computational load in early stages of acquisition. With advanced learners, intonation contour and prosodic balance play a greater role. This development suggests that L1 effects emerge with proficiency, presumably because reading in the L2 induces less computational load. This confirms that learners are sensitive to prosody and suggests that computational complexity limits the effect of prosody (Fultz, 2009). As we noted earlier, the French NSs tested in the US produced a solid N2 preference, echoing Dussias (2001), who argued that competing systems in bilinguals result in the use of a default attachment that follows from representational economy.

We now consider the tasks designed to capture an effect of the syntactic component. Dekydtspotter, Donaldson et al. (2008) found evidence suggestive of a syntactic reflex to minimize structure in the data from the intermediate In an online contextualized judgment task in which respondents first read stories providing context followed by sentences in a moving window presentation before indicating whether the sentences matched the context, shorter latencies were found in context disambiguating in favor of NP2 attachment versus NP1 attachment, even with a final preference for NP1 attachment. This is suggestive of a syntactic reflex to minimize structure impervious to context. In the current experiment, no clear patterns emerged for fourth-semester learners; however, for advanced learners, a NP2 attachment preference emerges in RTs, but only in the singular. Such a development suggests that the effect is consistent (a) with a syntactic reflex to parse input quickly (i.e., attachment of the RC to the closest NP, which is NP2) and (b) with computational complexity, because the singular is the default value. The fact that faster RTs are found with N2 interpretations, whether the disambiguation is morphological or contextual, is evidence of a syntactic reflex to minimize structure as the input is processed. This is modulated by processing load, which is itself determined by linguistic computations: first, relative accessibility of NP2 attachment versus NP1 attachment, given the need to minimize structure, and second, relative cost of processing, and, in particular, defaults versus specified values of the number feature. Therefore, costs inherent in each computation seem instructive of the nature of the processing of RCs by L2 learners.

6. Perspectives

Fourth-semester learners compute prosodic representations, computations which may be influenced by a segmentation strategy under severe computational load during acquisition: These prosodic representations either reinforce a syntactic bias or militate against it. This is compatible with other evidence. Examining effects of intonation contour in adjectival, PP, and RC modification, Fultz (2009) documented sensitivity to intonation contour in this order, and with increasing proficiency. (Early) Learners are sensitive to [N] [Mod] in adjectival and PPs but not in the case of RCs.

The evidence of distinct preferences in English-French Interlanguage (i.e., NP1 attachment preference in prosody and NP2 attachment preference in morphology) suggests that aspects of L2 processing result from the interaction of computational load with distinct mechanisms. This discrepancy points to a specific mental organization, showing modular processing by a universal algorithm (Dekydtspotter et al., 2006). Evidence of modularity threatens the shallow structures hypothesis according to which L2 learners process sentences in a fundamentally different way.

7. Appendix: The disambiguating verbs

Verb	3rd singular/3rd plural
revenir “come back”	revient/reviennent
partir “leave”	part/partent
sortir “go out”	sort/sortent
lire “read”	lit/lisent
dormir “sleep”	dort/dorment
boire “drink”	boit/boivent
prendre “take”	prend/prennent
descendre “go down”	descend/descendent
mettre “put”	met/mettent
maigrir “slim down”	maigrit/maigrissent
rendre “give back”	rend/rendent
faire “make”	fait/font
réussir “succeed”	réussit/réussissent
venir “come”	vient/viennent
finir “finish”	finit/finissent
rougir “redden”	rougit/rougissent
choisir “choose”	choisit/choisissent
écrire “write”	écrit/écrivent
dire “say”	dit/disent
conduire “drive”	conduit/conduisent

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