

# Second Language Processing of Filler-Gap Dependencies: Evidence for the Role of Lexical Access

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## 1. Introduction

Sentences that involve direct and indirect object relative clauses contain displaced syntactic constituents (or fillers) that do not appear in their canonical object position following the verb. During real-time comprehension, when the head of such a relative clause is encountered, it has been argued that the human sentence processing mechanism will automatically project a syntactic structure that includes a trace where the displaced element originated as an object of its licensing verb (e.g., Frazier, 1987; Frazier & Fodor, 1978). The referent of the filler, after it is accessed in the lexicon, will be temporarily stored in working memory, until the moment at which this trace (or gap) is encountered later during sentence processing and at which the filler can thus be retrieved from memory and integrated into the structure (e.g., Bever & McElree, 1988; Love & Swinney, 1996; Nicol & Swinney, 1989). Thus, processing a filler-gap dependency involves not only the computation of a movement chain but also the activation (i.e., initial retrieval from the lexicon) and maintenance (e.g., storage in working memory) of the referent of the filler. Furthermore, there is a crucial interaction between the two systems: Encountering the trace of a moved *wh*-expression triggers reactivation of the referent. Empirical research on the processing of filler-gap dependencies in a native language (L1) has revealed response patterns that are highly suggestive of mental reactivation of the filler at the structurally defined gap site from which it originated (e.g., Gibson & Warren, 2004; Love, 2007; Love & Swinney, 1996; Roberts, Marinis, Felser, & Clahsen, 2007). Among native speakers (NSs), evidence for this trace-induced reactivation is observed in longer reading times on segments that include a syntactic gap (e.g., Gibson & Warren, 2004) or in faster decision times in categorizing, at crucial moments, visually presented probes (images or words) that are related to the filler (e.g., Love, 2007).

The question of whether the same sentence processing mechanisms are available in adult second language (L2) acquisition has received much recent attention. A substantial body of research has shown that many of the same sources of information that NSs are able to deploy during online comprehension are also used in L2 sentence processing (e.g., Dekydtspotter, Donaldson, Edmonds, Liljestrang-Fultz, & Petrush, 2008; Frenck-Mestre, 2005; Frenck-Mestre & Pynte, 1997; Juffs, 1998, 2006; Juffs & Harrington, 1995; Omaki & Schulz, 2011; Williams, Möbius, & Kim, 2001). Although learner results may differ from NS results on some tasks, this does not necessarily point to more fundamental underlying differences between L1 and L2 processing (Dekydtspotter, Schwartz, & Sprouse, 2006). However, many others have argued that, in contrast to NSs—who show a clear syntactic reflex during processing—even advanced L2 learners seem to rely more heavily on nonsyntactic information (Clahsen & Felser, 2006a, 2006b; Felser & Roberts, 2007; Felser, Roberts, Marinis, & Gross, 2003; Marinis, Roberts, Felser & Clahsen, 2005). Clahsen and Felser's (2006a, 2006b) shallow structure hypothesis maintains that—due to the incomplete and imperfect nature of the L2 grammar, which cannot be called upon during online processing—L2 learners tend to overrely on semantic cues, contextual information, and real-world knowledge to assign meaning to linguistic input processed in real time.

For proponents of the shallow structure hypothesis, impaired grammatical representations are thus the main source of the supposed L1-L2 processing differences. This model fails to consider another plausible source of differing L1-L2 response patterns in experimental research—namely, the possible effects of under-routinized L2 lexical retrieval, which has been shown to be lacking in automaticity

among beginning and intermediate learners (Favreau & Segalowitz, 1983) and in speed among advanced learners (Segalowitz & Segalowitz, 1993). This is a serious oversight, given that much of the evidence often cited in support of the shallow structure hypothesis crucially depends on the (re)activation of referents during the processing of filler-gap dependencies (which necessarily involves activating and maintaining referents). Difficulties in lexical retrieval could thus presumably affect learner performance in experimental research that examines L2 sentence processing, leading to these supposed nonnative-like response patterns, irrespective of whether domain-specific structurally based representations are available to nonnative speakers.

It is thus important to consider the full range of computations, syntactic and otherwise, involved in the online processing of filler-gap dependencies. The current study reports on a priming experiment that compares response patterns for indirect object cleft sentences that involve French-English cognate animal names as antecedents with those that involve noncognate vocabulary. Reaction time (RT) asymmetries in a picture classification during reading task are examined for evidence of gaps.

## 2. Syntactic processing in L1 and L2

Evidence for the presence of traces as structural reflexes of (L1) sentence processing comes in part from studies that use the crossmodal priming methodology (e.g., Nicol & Swinney, 1989). In these experiments, participants seated at a computer are asked to make simple categorization decisions about probes that are presented visually at specific moments while at the same time listening to an auditory stimulus. Probes may be strings of letters to be identified as a word or nonword, or images to be classified according to some binary distinction, such as *±alive*. Probes are timed to appear concurrently with the gap position, where reactivation of the filler triggered by encountering the trace should facilitate classification decisions about probes that are semantically related or identical to the antecedent of the trace: RTs to related probes at the gap position are expected to be faster than those to unrelated probes appearing in the same position, and faster than those to related probes presented at other (usually earlier) control positions during processing.

The results of previous studies that have confirmed these predictions suggest that syntactic gaps are part of the sentence structure in online L1 processing. For example, Roberts et al. (2007) tested adult and child English NSs on a crossmodal priming task using sentences containing indirect object relative clauses, as in (1).

- (1) *Jo knew the ostrich to which the black spider explained the difficult [#1] problem [#2] at school last Monday.*

While listening to these sentences for comprehension, at the gap position (#2) or in a control position approximately 500 ms earlier (#1), participants pressed a button to classify identical and unrelated picture probes as alive or not alive. The identical probes matched the antecedent of the trace (as in a picture of an ostrich paired with this example), whereas the control probes depicted some unrelated inanimate object (such as a toothbrush or a carrot). Participants encountered periodic comprehension questions to hold them accountable for actively paying attention to the experimental items. In addition to the main experimental task, all participants also completed a working memory reading span test. Roberts et al. found clear priming effects, presumably related to the processing of a trace in canonical indirect object position: RTs to identical probes in the gap position were faster than those for unrelated probes at the same position, whereas RTs to the same two probe types in the control position did not reflect this facilitation for identical targets. However, only the children and adults with high working memory capacity demonstrated these priming effects.

Felser and Roberts (2007) tested 24 Greek-speaking adult advanced learners of English on the same stimuli used by Roberts et al. (2007), and compared these results against those of each of the four subgroups of NSs: low working memory adults, high working memory adults, low working memory children, and high working memory children. The learners' RTs were shorter for identical versus unrelated targets in both gap and control position, which Felser and Roberts interpreted as evidence for maintained activation of the antecedent throughout the sentence—as opposed to reactivation of the antecedent triggered by the presence of a trace at the gap position. Furthermore, no effect of working memory capacity was found among these learners. Felser and Roberts pointed out that the L2 participants behaved differently from all four subgroups of NSs in Roberts et al.'s study: Whereas the

learners exhibited facilitation effects for identical probes in both gap and control position, both the children and adults with high working memory capacity showed a position-specific advantage for identical probes at the gap position only; there were no significant differences between RTs to identical versus unrelated targets among the low working memory adults; finally, the low working memory children showed inhibition rather than facilitation effects, with RTs to identical probes that were actually longer when compared with those to unrelated probes in both positions, and much more so at the gap position (147 ms faster for unrelated probes, versus a 36 ms difference at the control position). Because the L2 learners produced a unique response pattern that did not appear anywhere in the NS data, Felser and Roberts interpreted this as evidence for an important difference between L1 and L2 processing—namely, that learners resort to shallow computations of the input in real time: The fact that the L2ers produced the same RT asymmetry regardless of position pointed to a lack of effect of structure.

It is important to note that Felser and Roberts's (2007) argument for L1-L2 processing differences focused on the supposed lack of evidence for nativelike syntactic computations, with no serious consideration for the role of nonautomatized lexical access (as discussed by Favreau & Segalowitz, 1983; Segalowitz & Segalowitz, 1993). However, the vocabulary used as antecedents in the experimental sentences may have affected the results. In addition to *ostrich* as in the example in (1), some of the animal names used as antecedents in the experimental items included *peacock*, *beetle*, *squirrel*, *camel*, *eagle*, *penguin*, and *donkey*, among others. Many of these are somewhat exotic animals, whose names even very advanced L2 learners may not have much occasion to use. It is not unreasonable to assume that learners' lexical access routines for such vocabulary would be under-routinized, thus inducing processing lags which in turn may have masked any benefit of structural computations.

An alternative explanation is that the pattern of asymmetry in Felser and Roberts's L2 results are due to the fact that the identical probes depicted things that had just been encountered in the sentences, whereas the unrelated probes represented something new that had not been previously mentioned. As noted by Nicol, Fodor, and Swinney (1994), there may be any number of factors that can affect response patterns in such studies, regardless of whether syntactic representations are computed. The predicted response pattern of the crossmodal priming methodology relies on two major assumptions: first, that the integration of a displaced filler into the sentence structure is mediated by encountering the trace (see, e.g., Pickering & Barry, 1991; Sag & Fodor, 1994; Traxler & Pickering, 1996, for arguments that filler integration is mediated by the verb's thematic structure); and second, that RTs to matching or related probes will reflect priming effects (see Dekydtspotter, Miller, Schaefer, Chang, & Kim, 2010, for a discussion of inhibition antipriming effects). Perhaps more important, however, is the crucial assumption that there will be an exact overlap between the trace-induced reactivation of the filler and the facilitation exhibited in the shorter RTs. Nicol et al. discussed the limited window of opportunity that this methodology affords for capturing the relevant effects, even in L1 processing experiments.

With respect to L2 sentence processing, Dekydtspotter et al. (2006) noted that there is no guarantee that NS and L2 learner response patterns will reflect the exact same processing moments. Similarly, Miller (2010) argued that experimental stimuli should be more tailored to L2 populations. In investigating L2 processing, researchers have generally assumed that experimental instruments that have shown the expected results among NS populations should also be able to capture the same effects among learners—if such effects are present. Divergent learner results on these tasks designed for NSs are thus interpreted as evidence for differences or limitations in L2 processing. Processing lags, perhaps due to underautomatized lexical access, may mean that any measurable priming effects could be masked.

### 3. Lexical retrieval during sentence processing in L1 and L2

In an exploration of how lexical access may affect sentence processing, Love, Maas, and Swinney (2003) tested for effects of lexical ambiguity in the processing of English as a L2, using a crossmodal naming task, a variant of the crossmodal priming paradigm. Rather than categorizing (picture) probes, in this task participants were asked to name (i.e., read) words that appeared on the computer screen as quickly as possible, while at the same time listening to an auditory stimulus. RTs were measured from the moment at which the probe word first appeared on the screen to the onset of the participant's

spoken response, which was recorded by the computer software. The expected pattern of RT asymmetries was the same as that for the crossmodal priming task used by Roberts et al. (2007) and by Felser and Roberts (2007). Advanced L2 learners of English from various L1 backgrounds were tested on sentences such as (2), in which the relativized direct object was deemed lexically ambiguous. It should be noted that the context of the sentence created a strong bias for the assumed primary meaning of the antecedent.

- (2) *The professor insisted that the exam be completed in ink, so Jimmy used the new pen [#1] that his mother-in-law recently [#2] purchased [#3] because the multiple colors allowed for more creativity.*

Probe words were related to either the primary or secondary meaning of the antecedent, or they were unrelated. For the sentence in (2), the primary meaning of the relativized direct object is “writing implement,” whereas the secondary meaning is “prison” (a rather obscure meaning which may result either from the truncation of *penitentiary* or from a more idiomatic sense of *pen* as “an enclosure for animals”). Related probes were thus *pencil* and *jail*, whereas the unrelated probes, which were matched for frequency and length, were *jacket* and *tale*, respectively. A first experiment revealed that at the first test position (#1), immediately following the antecedent, the L2 learners failed to produce any significant priming effects for probes that were related to either the primary or secondary meanings. This differs from the NS results from Love and Swinney (1996), who used the same stimulus: The NSs from that study produced faster RTs for probes related to both meanings of the ambiguous words used as antecedents. A second experiment tested for priming effects immediately preceding (#2) and following the verb (#3). At test position #2, the L2 learner participants exhibited significant priming effects for probes related to the primary meaning only. The NSs did not show any evidence of priming at this point. At position #3 (i.e., the gap site), whereas the NSs demonstrated significant priming effects for probes related to the primary meaning only, the L2 learners produced significantly shorter RTs for probes related to the secondary meaning of the antecedent.

Given that the NS and learner response patterns differed, Love et al. (2003) argued for L1-L2 processing differences, again focusing on the syntactic computations and the apparent absence of a trace to trigger reactivation among the L2 learners. With respect to lexical access during online comprehension, the overall conclusion was that both primary and secondary meanings of lexically ambiguous words will be accessed during sentence processing, among NSs and L2 learners alike, even when the context is strongly biased toward the primary meaning. However, beyond this similarity, the NS and L2 response patterns also seem to suggest important differences in lexical retrieval, a point that Love et al. do not directly address. The NSs of Love and Swinney (1996) were able to quickly access both meanings of the ambiguous word, as indicated by the priming effects found at test position #1, and then to focus on the relevant meaning such that no priming effects occurred for the secondary meaning at the gap site in position #3. The fact that no priming effects were found in the L2 learner data at position #1, immediately after the filler was encountered, suggests that the initial activation of the corresponding referent was slower, presumably due to underautomatized L2 lexical access. This finding is consistent with previous research that has shown that word recognition is slower and less automatic in L2 (Favreau & Segalowitz, 1983; Segalowitz & Segalowitz, 1993). Moreover, the pattern of priming effects found in positions #2 and #3 could indicate that L2 lexical access is not only slower but also staggered. The primary meaning was accessed first, followed by the secondary, and—at least in the case of this example—more obscure meaning. It is important to note, however, that although the L2 results did differ from those of the NSs, they do not seem to be compatible with the notion of shallow representations: If the learners were using a shallow processing routine to segment the input into chunks and to use contextual information to determine the meaning relations between those chunks, then they would not be expected to access all possible meanings of the filler—especially given that the sentential context was highly biasing toward the primary meaning of the antecedent. Thus, the results of this study seem to suggest that lexical access plays an important role in sentence processing and that although learners may be a bit slower than NSs in this respect, they may not necessarily be processing shallowly.

## 4. The current study

### 4.1. Materials

Motivated by the possibility that difficulties related to underautomatized lexical access routines may have masked the structural effects of processing in previous studies on L2, the current study endeavors to determine whether L2 learners might be able to produce more targetlike experimental results when lexical retrieval is facilitated through the use of cognate vocabulary. To this end, a priming experiment was designed to further explore patterns of filler (re)activation during online sentence processing among L2 learners of French. This experiment involved indirect object cleft sentences as in (3)—similar to the sentences used by Felser and Roberts (2007) to examine L2 English processing, but less complex in that the cleft structure involves one fewer referent: The sentence in (4) from Felser and Roberts' study introduces three referents into the mental model of the discourse context (i.e., *Fred, the squirrel, the monkey*). As noted by Gibson (1998) and Gibson and Warren (2004), the cost of maintaining a referent in memory is proportional to the number of referents introduced in the discourse context. The cleft structure in (3), in contrast, introduces only two referents, thus allowing for processing resources to be focused elsewhere, presumably facilitating maintenance of the filler in memory until the trace is encountered.

(3) *C'est au gorille que Cécile a envoyé le petit cadeau chez lui jeudi matin.*

"It's to the gorilla that Cécile sent the small gift at his house Thursday morning."

(4) *Fred chased the squirrel to which the nice monkey explained the game's difficult rules in the class last Wednesday.*  
(Felser & Roberts, 2007)

To investigate the possible effects of under-routinized lexical retrieval, the current study compared RT patterns for sentences that used cognate animal names as antecedents in indirect object cleft sentences with those for sentences that used noncognate animal names as antecedents. Thus, half of the experimental items involved cognate fillers (such as *gorille* "gorilla") and the other half involved noncognate fillers. The complete list of both cognate and noncognate animal names is given in Table 1. For the purposes of the current experiment, cognate vocabulary is operationalized as forms that are essentially homographic in English and French and that share the same referents. The cognate vocabulary in Table 1 would be easily recognizable to an English speaker—even one who does not speak French. The use of cognates was thus assumed to facilitate lexical access among L2 learners, by providing an extra boost from the L1 (see, e.g., Cia, Pickering, Yan, & Branigan, 2011; Hoshino & Kroll, 2008).

Table 1. *Cognate and Noncognate Vocabulary Used as Antecedents*

Cognates		Noncognates	
French	English	French	English
<i>crocodile</i>	crocodile	<i>abeille</i>	bee
<i>éléphant</i>	elephant	<i>araignée</i>	spider
<i>girafe</i>	giraffe	<i>baleine</i>	whale
<i>gorille</i>	gorilla	<i>canard</i>	duck
<i>hamster</i>	hamster	<i>chèvre</i>	goat
<i>hippopotame</i>	hippopotamus	<i>corbeau</i>	crow
<i>léopard</i>	leopard	<i>cygne</i>	swan
<i>lézard</i>	lizard	<i>fourmi</i>	ant
<i>lion</i>	lion	<i>grenouille</i>	frog
<i>panda</i>	panda	<i>hibou</i>	owl
<i>panthère</i>	panther	<i>hirondelle</i>	swallow
<i>rat</i>	rat	<i>papillon</i>	butterfly
<i>rhinocéros</i>	rhinoceros	<i>phoque</i>	seal
<i>serpent</i>	snake	<i>renard</i>	fox
<i>tigre</i>	tiger	<i>requin</i>	shark
<i>zèbre</i>	zebra	<i>singe</i>	monkey

The cognate and noncognate terms were matched for frequency. All L2 participants received training on both cognate and noncognate vocabulary approximately one week before completing the main experimental task. This training consisted of a PowerPoint presentation that included photos of animals (different from the drawings used in the experimental task) labeled with their names in French and simple matching, association, and categorization activities that allowed the learners to use the new vocabulary. The training activities were designed to ensure that the learner participants had at least some prior exposure to the relevant vocabulary.

#### 4.2. Methodology

Because classroom learners are accustomed to written input, the current study uses a reading methodology developed by Dekydtspotter et al. (2010) and used in Miller (2010, 2011): probe classification during reading. This task pairs the classification of picture probes, as in the crossmodal priming methodology, with forced-paced reading aloud. Whereas the crossmodal priming task requires participants to respond to questions related to the content of the sentences—which means that it is essentially a listening comprehension exercise—having participants read aloud rather than listen and respond to comprehension checks removes some of the complexity, thus allowing for more resources to be focused on sentence processing. Additionally, for the purposes of the current study, the reading modality better allows for the cognate-noncognate comparison: Although the cognate forms share similar orthography in English and French, the pronunciation in the two languages can differ quite a bit. For example, the word *hamster*, pronounced [hæmstəʃ] in American English, is pronounced [amstɛR] in French. Similarly, *lion* is pronounced [ljɔ̃] in French but [laɪən] in English. Thus, these homographic cognate words might not be as quickly and easily recognizable when encountered aurally in a crossmodal priming experiment.

It should be noted that previous research (McKoon & Ratcliff, 1994; Nicol, Swinney, Love, & Hald, 2007) has suggested that an all-visual presentation, in which the sentence is interrupted by the appearance of the probe, may be more susceptible to congruency effects than the crossmodal priming paradigm. In other words, the processing mechanism may attempt to integrate the probe as part of the structure of the interrupted sentence. This could prove problematic as it may potentially create an illusion of priming. However, these previous studies paired forced-paced reading with a lexical decision task: Participants were asked to identify strings of letters that intervened during reading as words or nonwords. The probes were presented slightly offset from the center and in all capital letters to differentiate them from the sentence. Nonetheless, participants exhibited faster RTs when the probe word could be easily integrated into the structure. The current study used pictures instead of words as probes in an attempt to minimize this type of effect, as visual processing is separate from language processing (e.g., Jackendoff, 1987; Marr, 1982). This methodology is thus expected to elicit priming effects similarly to studies in the crossmodal priming paradigm.

The experimental stimulus consisted of 32 critical items, of which 16 used cognate animal names as antecedents and 16 involved noncognate antecedents. Picture probes were cartoon images of animals that matched the referent of the filler or depicted unrelated inanimate objects. A  $2 \times 2$  design crossed probe type (filler matching or nonmatching) with position (gap or control) to create four versions of each experimental item. Each participant encountered only one version of each sentence, but equal numbers of sentences in all four conditions. An example cognate item is given in (5), and a noncognate item is given in (6). Examples of the picture probes used with these items are shown in Figure 1.

- (5) a. Condition 1: filler-matching probe, gap position  
*C'est / à l'éléphant / que / Sarah / a expliqué / le nouveau / jeu / [picture probe: ELEPHANT] / chez lui / vendredi matin.*
- b. Condition 2: nonmatching probe, gap position  
*C'est / à l'éléphant / que / Sarah / a expliqué / le nouveau / jeu / [picture probe: BICYCLE] / chez lui / vendredi matin.*
- c. Condition 3: filler-matching probe, control position  
*C'est / à l'éléphant / que / Sarah / a expliqué / le nouveau / [picture probe: ELEPHANT] / jeu / chez lui / vendredi matin.*
- d. Condition 4: nonmatching probe, control position

*C'est / à l'éléphant / que / Sarah / a expliqué / le nouveau / [picture probe: BICYCLE] / jeu / chez lui / vendredi matin.*

"It's to the elephant that Sarah explained the new game at his house Friday morning."

- (6) a. Condition 1: filler-matching probe, gap position

*C'est / au papillon / que / Robert / a offert / le nouveau / ballon / [picture probe: BUTTERFLY] / dans le jardin / lundi soir.*

- b. Condition 2: nonmatching probe, gap position

*C'est / au papillon / que / Robert / a offert / le nouveau / ballon / [picture probe: CALCULATOR] / dans le jardin / lundi soir.*

- c. Condition 3: filler-matching probe, control position

*C'est / au papillon / que / Robert / a offert / le nouveau / [picture probe: BUTTERFLY] / ballon / dans le jardin / lundi soir.*

- d. Condition 4: nonmatching probe, control position

*C'est / au papillon / que / Robert / a offert / le nouveau / [picture probe: CALCULATOR] / ballon / dans le jardin / lundi soir.*

"It's to the butterfly that Robert gave the new ball in the garden Monday evening."

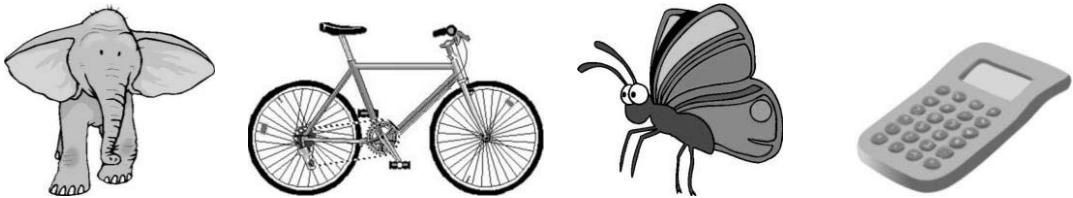


Figure 1. Examples of *alive* and *not alive* picture probes.

An additional 48 sentences with a similar structure were created as distracters. Like the main experimental items, the distracters involved probes that depicted animals and inanimate objects, but appearing in various positions throughout the sentences, thus creating the impression that either type of probe could appear at any point during reading.

#### 4.3. *Participants and procedure*

A context was provided in which a group of French schoolchildren had just returned from a week-long trip to an enchanted zoo, where they had befriended the animal inhabitants. Back in class, they were talking about the events of the previous week with their teacher, who was having trouble remembering the details of what had happened. Participants sat in front of a computer screen and were asked to read aloud to themselves in a low voice, paying careful attention to the sentences, and to indicate, as quickly as possible, whether an interrupting image depicted something alive or not alive by pressing a button. Each sentence segment appeared in the center of the screen for 500 ms + 20 ms per letter. Picture probes appeared for 650 ms. DMDX software (Forster & Forster, 2003) was used to measure response times, and to control reading speed.

I report here on the results from a group of NSs ( $n = 15$ ) and three learner groups: beginning ( $n = 17$ ), low intermediate ( $n = 17$ ), and high intermediate ( $n = 15$ ). Participant characteristics are shown in Table 2. The L2 learners were undergraduate students at a large Midwestern university, enrolled in a second-semester (beginning), fourth-semester (low intermediate), or 300-level (high intermediate) course at the time of testing. However, as can be seen by the average length of study reported in Table 2, many of the learners had had some high school French (however, all had begun their study of French at or after the age of 12). The L1 of all learner participants was American English. The NSs were graduate students or post-doctoral researchers at the same university.

All participants completed a background questionnaire and a working memory reading span test adapted from Harrington and Sawyer (1992) for L2 French. Because working memory capacity was not found to have a significant effect on RT patterns (thus echoing Felsler and Roberts's, 2007, findings), the results of this task are not reported here.

Table 2. *Participant Characteristics*

Group	Age	Years of study	Months abroad
Beginning ( $n = 17$ )	18.7 (0.9)	4.2 (0.9)	0.2 (0.6)
Low intermediate ( $n = 17$ )	19.6 (1.7)	6.0 (2.5)	0.2 (0.6)
High intermediate ( $n = 18$ )	21.3 (4.5)	7.1 (2.1)	0.2 (0.3)
Native ( $n = 15$ )	29.0 (2.7)	<i>n.a.</i>	<i>n.a.</i>

*Note:* Standard deviations are in parentheses.

#### 4.4. Analysis and predictions

Only RTs for which an image was identified correctly as alive or not alive were included for analysis. All participants were highly accurate in their classification of images, with less than 2% of the data excluded due to incorrect classifications. Data pruning affected an additional 5% of the data: Within each participant group, any RT that fell outside two standard deviations from the mean was removed and replaced by the new group mean. A  $2 \times 2 \times 2$  ANOVA investigated the effects and interactions of probe position and probe type as well as cognate status of the filler. Planned paired-samples  $t$  tests, with one-tailed  $\alpha$  (given expectations of facilitation due to matching probes) set at .05, were used to determine whether any asymmetries in the mean RTs in each condition were statistically significant. If processing is structurally based, and if learners use syntactic gaps to resolve filler-gap dependencies, RTs are expected to be shorter when a picture probe appearing at the moment the gap is encountered matches the antecedent than when the image does not match. Additionally, RTs for matching probes in gap position are also predicted to be faster than those to matching pictures appearing in the control position. No other significant RT differences are expected. The predicted RT pattern is shown in Figure 2.

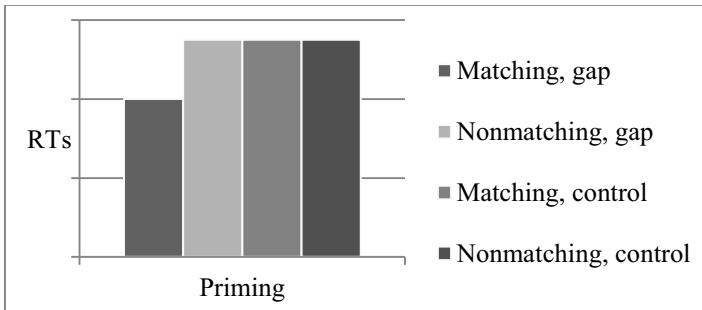


Figure 2. Expected RT asymmetries showing facilitative priming effects.

## 5. Results

A repeated measures ANOVA with position, probe, and cognate status as within-subject factors and participant group as a between-subject factor revealed a significant three-way interaction between position, probe, and cognate status,  $F(1, 60) = 7.793$ ,  $p < .01$ , which was further qualified by participant group,  $F(3, 60) = 4.591$ ,  $p < .01$ . The Position  $\times$  Probe  $\times$  Cognate interaction was maintained in the beginning,  $F(1, 16) = 8.039$ ,  $p < .05$ , and high intermediate,  $F(1, 14) = 22.570$ ,  $p < .001$ , learner groups, and approached significance in the low intermediate learner data,  $F(1, 16) = 4.271$ ,  $p = .055$ .

Each group's mean RTs for cognate and noncognate items are reported in Table 3, and illustrated in Figure 3.

Table 3. RTs (in ms) to Picture Probes for Cognate and Noncognate Items

Condition	Beginning ( <i>n</i> = 17)		Low intermediate ( <i>n</i> = 17)		High intermediate ( <i>n</i> = 15)		Native ( <i>n</i> = 15)	
	Cognate	Non-cognate	Cognate	Non-cognate	Cognate	Non-cognate	Cognate	Non-cognate
Matching, gap	490 (60)	521 (64)	514 (50)	547 (49)	491 (71)	511 (86)	519 (52)	512 (86)
Nonmatching, gap	527 (55)	512 (57)	548 (49)	551 (51)	518 (81)	497 (71)	509 (91)	531 (76)
Matching, control	493 (65)	485 (59)	538 (60)	538 (43)	513 (70)	481 (68)	509 (67)	521 (58)
Nonmatching, control	513 (57)	530 (81)	555 (53)	543 (67)	493 (62)	520 (77)	524 (70)	530 (65)

Note: Standard deviations are in parentheses.

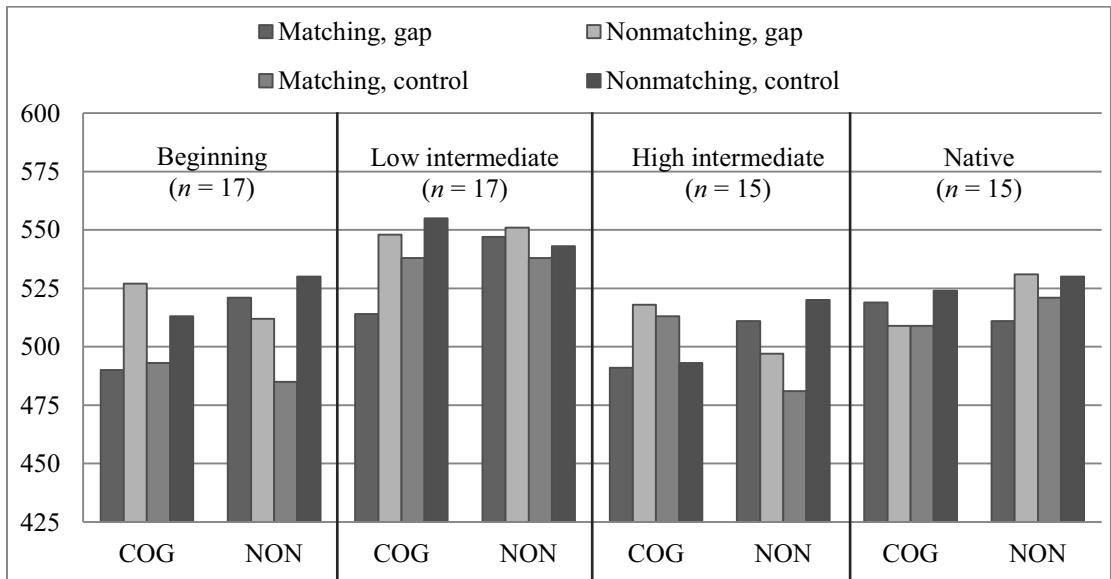


Figure 3. RTs (in ms) to picture probes for cognate (COG) and noncognate (NON) items.

As can be observed in Figure 3, all participant groups exhibited differing RT patterns to cognate and noncognate items. The beginning learners responded more quickly to picture probes that matched cognate antecedents in both gap,  $t(16) = 3.169, p < .01$ , and control position,  $t(16) = 2.069, p < .05$  (one-tailed), thus reproducing the pattern revealed among the advanced learners of Felser and Roberts (2007). However, with noncognate items, these learners produced a different pattern, exhibiting the shortest RTs to matching probes in the control position. Both groups of intermediate learners produced the predicted priming pattern, with faster RTs to matching versus nonmatching probes in gap position; low intermediate,  $t(16) = 2.958, p < .01$ , high intermediate,  $t(14) = 2.528, p < .05$ ; and to matching probes in gap versus control position; low intermediate,  $t(16) = 1.897, p < .05$  (one-tailed), high intermediate,  $t(14) = 1.871, p < .05$  (one-tailed). However, this effect is only found for the cognate items; with noncognate items, the low intermediate learners exhibited flat RTs across all conditions, whereas the high intermediate learners responded most quickly to the matching probes in the control position, echoing the beginning learner RT pattern for the noncognate items. Finally, although the NSs also produced differing patterns for cognate and noncognate items, these differences contrast with those exhibited by the learner groups in that the NSs seem to produce a more targetlike priming pattern with the noncognate (rather than cognate) items. Although suggestive of reactivation effects, however, these RT asymmetries do not reach statistical significance.

## 6. Discussion

RT patterns to cognate and noncognate items differed in all L2 participant groups. In the learner data, three distinct patterns emerged. A pattern similar to that produced by the advanced learners in Felser and Roberts (2007) was revealed in the beginning learner data, with shorter RTs to picture probes that matched cognate antecedents than to unrelated probes. For Felser and Roberts, this pattern pointed to maintained activation of the filler throughout processing as opposed to trace-induced reactivation of the filler from temporary storage in memory. The asymmetry between RTs to matching versus nonmatching probes was the same in both positions, which, as Felser and Roberts argued, may indicate a lack of structure during sentence processing. However, as mentioned earlier, this pattern may simply reflect the fact that the matching probes depicted an animal that matched a referent that had just been activated into the discourse context whereas the nonmatching probes depicted something unrelated that seemed to come out of the blue. Thus, this type of pattern would seem to reflect the salience of the filler. This pattern was only produced with cognate items and among the lowest level learners.

With noncognate items, the beginning learners responded most quickly to matching probes in the control position. This pattern was also revealed in the high intermediate learner data, also in response to noncognate items. This RT pattern may indicate an activation that fades as processing proceeds. Recall that the control position occurred earlier in the sentence; the linear distance between the filler and the gap position is greater than that between the filler and the control position. Thus, it may be assumed that following the initial retrieval of the referent of the filler from the lexicon, the activation began to fade as processing proceeded. This type of pattern may thus simply reflect the recentness of the filler, with the shortest RTs associated with the closest (i.e., control) test position. However, if this pattern is to be attributed to recency effects, we might also expect to find a (slightly lesser) facilitation effect at the gap position, which occurs just one segment (approximately 500-600 ms) later. However, RTs in the gap position were flat. Another possible explanation is that this pattern reflects a delay in the initial activation of the referent of the antecedent: If the initial activation of the referent was delayed as a result of underautomatized lexical access to this newly learned noncognate vocabulary, the effects of this initial retrieval from the lexicon may be reflected in the shorter RTs to the matching probes in the control position. Furthermore, reactivation at the gap site may have similarly been delayed, resulting in flat RTs in this position. Indeed, Angwin, Chenery, Copland, Cardell, Murdoch, and Ingram (2006) pointed out, in the context of L1 processing, that “since trace reactivation effects are dependent on rapid information processing, delays in semantic activation would be expected to interfere with both the initial activation of the antecedent and its subsequent reactivation” (p. 112). This pattern is thus consistent with expectations of processing lags due to difficulties associated with lexical access routines for the less familiar vocabulary items.

The third (and most important) pattern is the predicted priming pattern (as illustrated in Figure 2), with the shortest RTs to matching probes in the gap position. This pattern was produced by low and high intermediate learners in response to cognate items only. It should be noted that this pattern cannot be attributed to the salience of the filler—which would manifest itself in shorter RTs in both positions, as in the pattern produced by the beginning learners for the cognate items—or to linear distance—which would presumably lead to shorter RTs in the earlier control position, as in the pattern produced by both beginning and high intermediate learners with noncognate items. This priming pattern, which has been found for NSs in L1 processing studies, is consistent with temporary storage of the filler during processing and subsequent reactivation triggered by encountering the trace. Crucially, however, such priming effects were not produced in response to noncognate items.

In contrast, it was in response to the noncognate items that the NS data presented a similar pattern suggestive of priming. Although these data seem to show the predicted priming effects, however, the RT asymmetries were not statistically significant. Furthermore, RTs to cognate items showed no discernible pattern. It might be expected that the more robust results would be found in the NS data—irrespective of whether the antecedent of the *wh*-filler were a French-English cognate term—rather than among (intermediate) L2 learners. However, recall that these NS participants were French-English bilinguals living and working in the United States at the time of testing. The NS results patterns (or lack thereof) may be due to an interference effect from the participants’ L2 English induced by the use of cognate vocabulary. Encountering a cognate animal name could have activated the L2, which may have increased the processing load, thereby masking the benefits of structural

processing or inducing a shallow processing routine (see Townsend & Bever, 2001). With noncognate items, the L2 could have been more easily suppressed, thus yielding more targetlike results—although, as noted by, for example, Grosjean, 1989, the other language is never completely deactivated while one is being used.

It is important to note, however, that no real conclusions can be drawn based on the NS data. The main focus of this study was on learner development. In sum, although the beginning learners produced a RT pattern resembling that produced by the advanced L2 English learners of Felser and Roberts's (2007) study, the (low and high) intermediate learners of the current study produced the predicted response pattern, only when activation and maintenance of the filler was facilitated through the use of cognate vocabulary as antecedents in indirect object cleft sentences. This finding points to lexical retrieval as an important factor affecting L2 sentence processing. When the range of patterns and the circumstances in which each occurs are considered overall, the results of the current study seem to indicate that L2 learners are indeed capable of producing so-called nativelike results in sentence processing experiments, provided that lexical access routines and the possible effects thereof are taken into account.

## 7. Conclusion

Previous research in the crossmodal priming paradigm has concluded that the absence of the relevant asymmetries among learners points to differences in L1 and L2 sentence processing. The focus has been on the grammatical computations as the presumed source of these differences, with little consideration for the possible effects of lexical access routines, which are slower and less automatic in L2. However, the results of the current study suggest that difficulties associated with underautomatized lexical access can affect priming patterns produced by L2 learners in experimental research. This finding highlights the importance of considering the full range of computations, syntactic and otherwise, that are involved in the (L2) processing of filler-gap dependencies. This study constitutes a first exploratory step in gaining a better understanding of the myriad factors that may affect sentence processing.

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# Selected Proceedings of the 2011 Second Language Research Forum: Converging Theory and Practice

edited by Erik Voss,  
Shu-Ju Diana Tai, and Zhi Li

Cascadilla Proceedings Project Somerville, MA 2013

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