Investigating real-time sentence processing in the second language

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Second language (L2) acquisition researchers have always been concerned with what L2 learners know about the grammar of the target language but more recently there has been growing interest in how L2 learners put this knowledge to use in real-time sentence comprehension. In order to investigate real-time L2 sentence processing, the types of constructions studied and the methods used are often borrowed from the field of monolingual processing, but the overall issues are familiar from traditional L2 acquisition research. These cover questions relating to L2 learners' native-likeness, whether or not L1 transfer is in evidence, and how individual differences such as proficiency and language experience might have an effect. The aim of this paper is to provide for those unfamiliar with the field, an overview of the findings of a selection of behavioral studies that have investigated such questions, and to offer a picture of how L2 learners and bilinguals may process sentences in real time.

Introduction

In real-time sentence comprehension, as each word is encountered in listening or reading, an attempt is made to integrate it into the analysis of the sentence that has been constructed so far. This means that in order to interpret a sentence, one must apply grammatical knowledge (one must *parse* the sentence) and one must also access and integrate semantic, pragmatic, discourse and world knowledge information to ensure the appropriateness and plausibility of the interpretation (for overviews of parsing models, see e.g., De Vincenzi & Lombardo, 2000). Recently, there has been growing interest in how L2 learners process sentences in the target language, with research being guided by questions from the field of L2 acquisition and bilingualism research:
– how do L2 learners process the target language in comparison to native speakers?
– does the L1 influence L2 learners' moment-by-moment processing decisions?

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–   what is the effect of individual factors (e.g., proficiency and the amount, type and age of exposure)?

The paper is organized as follows. In the first section, the focus is on the processing of syntactic ambiguities, that is, constructions where the parser can choose between more than one grammatical analysis. Investigating what the parser decides to do when there is a choice offers insight into the nature of the mechanism, and in particular, its processing preferences. In the second section, the focus is on research into the processing of syntactic dependencies. Studying the moment-by-moment processing of this type of construction allows for an investigation of how and when different kinds of information (e.g., syntactic, semantic, pragmatic) are put to use in real-time comprehension. In sum, the aim of the paper is to see how such findings are helping to address the question of what the human sentence processor is like when the speaker has more than one language available.

Processing ambiguities

Many studies that have looked at how L2 learners process temporarily ambiguous sentences have found that L2 learners perform like native speakers. For example, in a word-by-word self-paced reading study (also known as *the moving window technique*, Just, Carpenter, & Woolley, 1982), Juffs and Harrington (1995) asked their Chinese L2 learners of English to read sentences, and then to judge the grammaticality of each one at the end. In this type of task each word in a sentence is brought up on a computer screen when the reader pushes a button and the time it takes for each button-push is recorded, and thus a measure of comparative processing ease and difficulty is obtained. The authors found that L2 learners slowed down when reading the main verb *proved* in constructions with optionally transitive verbs like *drink* [1a], in comparison to the same position in unambiguous sentences with intransitive initial verbs [*arrive*] as in [1b], where no such processing difficulty was observed because no direct object is expected.
[1a]   After Bill drank the water proved to be poisoned.
[1b]   After Sam arrived the guests began to eat and drink.

The construction shown in [1a] is a typical 'garden-path' sentence. That is, on encountering the noun phrase (NP) *the water*, the parser immediately attempts to integrate it into the current analysis, and thus the reader takes this NP to be the direct object of the previous verb [*drank*]. It is assumed that the processor prefers this direct object analysis, because structurally it is the 'least-effort' option (for the range of models accounting for this parsing preference, see, e.g., Frazier, 1979; Gibson, Pearlmutter, Canseco-Gonzalez, & Hickok, 1996; Gorrell, 1995). However, in [1a] the next word that appears in the input is a verb [*proved*], which requires a subject, and at this point

it is clear that the initial analysis of the NP *the water* was incorrect; it must now be reanalysed as the subject of the verb *proved*, rather than the direct object of the previous verb *drank*, and this causes (comparative) processing difficulty. When reading the sentences, the L2 learners in this study showed similar processing difficulty as the native English control group, showing that they too had initially been 'led down the garden-path'.

In [1a], the ambiguous NP *the water* is a plausible direct object of the verb *drink*, but the question arises as to how L2 learners treat *implausible* direct objects in comparison. This has been investigated, for instance, in Felser & Roberts (2004), where advanced Greek L2 learners of English read sentences like [2]. The authors compared the participants' word-by-word reading times of sentences with plausible ambiguous NPs [*wrote the book*] to those where a direct object analysis would lead to an implausible sentence fragment [*wrote the girl*].

[2]   The journalist wrote *the book/the girl* had amazed all the judges.

The results of this study showed that like the native English speaking control group, the L2 learners had more trouble reading the disambiguating verb *had amazed* when the NP was a highly plausible direct object of the verb as in *wrote the book*. That is, the L2 learners, like native speakers, were more committed to this analysis, and so had much more difficulty recovering from this error in analysis in comparison to the implausible condition. In sum, these studies show that like native speakers, L2 learners also incrementally process sentences in real time, attempting to integrate each new word into the current analysis as soon as it is encountered in the input (see also, Juffs, 1998; 2004), and that they are very sensitive to plausibility information in their on-line processing (see also, Williams, Möbius, & Kim, 2001), with such semantic information affecting how strongly they commit to their on-line analyses and how well they recover from initial misanalyses.

 In the above study, care was taken to minimize potential L1 influences and so the verbs used were matched between Greek and English in their subcategorisation properties. However, this potential L1 effect has been a research question in its own right. For instance, Frenck-Mestre & Pynte (1997) included sentences like those in [3] to see if their participants would be influenced by the subcategorisation properties of their L1 in their study of English-French bilinguals' on-line reading, using the eye-tracking during reading methodology. Like self-paced reading, this method takes reading time as the dependent measure, but it has the added benefit of not requiring the reader to make any strategic responses (Rayner & Pollatsek, 1989).

[3]   Chaque fois que le chien obéssait la jolie petite fille montrait sa joie.

In French, *obéir*, is obligatorily intransitive, whereas the English translation *obey* can be used either transitively or intransitively. Therefore, the authors predicted that if

English-French bilinguals were under the influence of their L1 (English), they might treat the verb *obéssait* as optionally transitive (as *obey* is in English), and therefore they might initially analyse the NP *la petite fille* as its direct object. They might then show a garden-path effect at the point of disambiguation, unlike native French speakers. Interestingly, the authors found that the fixation data showed a brief influence of such lexical differences between the L1 and the L2, since the bilinguals hesitated while reading those verbs which differed in subcategoris/ zation properties between the L1 and the L2. However, this was a very brief effect, since after this hesitation the learners processed the sentences in a native-like way.

Another type of ambiguity that has been investigated in the L2 processing field is the so-called relative clause (RC) attachment ambiguity, illustrated in [4].

[4]   The headmaster called to the pupil of the teacher who was thinking about the school play.

The complex sentence in [4] is globally ambiguous in that the RC *who was thinking about the school play* can modify either the first NP *the pupil* or the second NP *the teacher* of the preceding complex. Interestingly, speakers of different languages differ with regards to which noun they prefer the RC to modify, that is, they differ in their preferred *attachment site*. For instance, with a sentence like [4] English speakers will prefer the RC to modify NP2, so that it is *the teacher* who is interpreted as *thinking about the school play*. In contrast, for Greek and German speakers, in a translation of [4] it would be NP1 that is most often interpreted as the host of the RC, *the pupil.* Given this difference in parsing preferences between English on the one hand and Greek and German on the other, Felser, Roberts, Gross, & Marinis (2003) investigated whether their advanced Greek and German L2 learners would show an English-like NP2 preference, or whether they would transfer their native NP1 preference to the L2 input. Self-paced reading was the method used, and disambiguation was achieved by number agreement between the auxiliary verb in RC and one of two NPs in the preceding NP complex, as illustrated in [5].

[5]   The headmaster called to the pupils of the teacher who *was/were* thinking about the school play.

On reading the critical segment (*was* or *were*) where disambiguation takes place, the English control group indeed spent longer when the attachment of the RC was pushed towards the first NP in comparison to when attachment was pushed towards their preferred attachment site, NP2. Interestingly, neither of the L2 learner groups had a preference for either NP1 or NP2 attachment, since they showed no significant difference in reading times between the two conditions. So there was no evidence in this study of either target-like parsing preferences (NP2), or an influence from the learners' L1 (NP1) in this respect. The authors assume that the observed (monolingual) cross-linguistic parsing preferences are driven by structurally-based principles, with the NP2

preference found with English speakers being derived from a locality-based principle pushing for the RC to be attached to the most recent NP in the preceding complex (for more details, see e.g. Mitchell & Brysbaert, 1998). It was not the case, however, that the L2 learners could not be garden-pathed at all with this type of RC ambiguity, since when more lexical-semantic information was available, the L2 learners performed like native speakers. That is, all groups showed an on-line preference for NP2 attachment when the NP complex contained a lexical (thematic) preposition (*with* in English) instead of a genitive, which is thought to restrict the current processing domain to only NP2 in these types of constructions (Frazier & Clifton, 1996). Thus the learners appeared not to have any preferences on-line when only structural information was available, but when thematic information dictated the available attachment site for the RC (as in the *with* sentences), the L2 learners performed like native-speakers.

As stated above, none of the L2 learners showed any on-line preference at all in their processing of the genitive relative clauses, and this was also the case in their off-line interpretations (compare learners in Dussias, 2003; Fernández, 1999). It is possible, however, that the learners were not quite proficient enough, and were caught at a time when they were 'on their way' towards a target NP2 processing preference. This is unlikely however, since the learners were at an advanced level of proficiency at the time of testing, and at least for the Greek L2 learners, no differences in processing preferences were found as a function of any language background variable tested, including English proficiency score and age of exposure (Roberts, 2003). A more compelling argument against L1 transfer (plus transition towards the target given enough L2 experience) comes from the results of a comparable on-line self-paced reading study of Spanish, German and Russian L2 learners of Greek (Papadopoulou & Clahsen, 2003) where very similar results were found. That is, even though the native speakers of all the L2 learners' first languages had been found to have identical attachment preferences to Greek speakers (i.e., NP1), the learners in this study performed like the Greek learners in the Felser et al. (2003) study, with no on-line preference for either NP1 or NP2 attachment in genitive RCs (although again, they had a preference for NP2 attachment with the thematic preposition, *me* = with). Thus it seems that transfer (plus enough exposure to the L2 input) cannot account for these findings, since should transfer of parsing preferences have taken place, then the German, Spanish and Russian L2 groups should have performed like the native Greek speakers in this study, (with a preference for NP1). A crucial point can be raised here: when investigating potential L1 influences, a group is also needed which is predicted to perform like the control group in order to tease apart potential L1 transfer effects, from the possible 'general effects' of being an L2 learner.

Taken together, the results from these studies suggest that when processing ambiguous constructions in the L2, learners perform similarly to native speakers; rapidly and effectively using lexical-semantic, thematic and/or plausibility information to analyse

the input on-line. As regards potential influences from the learner's first language, differences in the lexical-semantics of the L1 and the L2 might have a fleeting effect, but appear to hardly trouble on-line comprehension in the L2. However, L2 learners' processing may differ with regard to the use of syntactic information. Specifically, when lexical-semantic information is not available to inform on-line analyses and L2 learners must rely only on syntactic information in the input, they may suspend (or postpone) their processing decisions, irrespective of the properties of their L1.

Processing dependencies

Another set of studies attempting to address questions relating to the nature of L2 real-time sentence processing has focused on the processing of syntactic dependencies, for instance, English *wh*-dependencies like [6], taken from Marinis, Roberts, Felser, & Clahsen, (2005), a self-paced reading study. The authors investigated the processing of such sentences by Japanese, Chinese, Greek and German L2 learners of English.

    [6]   The nurse who the doctor argued __ that the rude patient had angered __ is refusing to work late.

This type of English dependency is similarly formed in Greek and German, with the *wh*-item extracted from its base position after *angered* and moved to a fronted position, whereas Japanese and Chinese do not have similar *wh*-movement (see Marinis et al. 2005 for full details of the linguistic and psycholinguistic assumptions underlying this study). Thus Marinis et al. (2005) were able to see firstly whether L2 learners would process such long-distance dependencies like native English speakers, and secondly, whether performance would differ as a function of L1 background. Like the native English control group, all the L2 learners showed evidence of linking or integrating the fronted item *the nurse* with the subcategorising verb *had angered*, since reading times were higher at this verb in [6] compared to the same position in the control condition where no such fronted element needed to be integrated [7].

    [7]   The nurse thought the doctor argued that the rude patient had angered the staff at the hospital.

This finding is unsurprising since this linking of the dislocated item with its sub-categoriser needs to take place for successful comprehension to be achieved, and it is clear that L2 learners can perform such integration on-line as has been shown in other studies (e.g., Frenck-Mestre, 2002; Frenck-Mestre & Pynte, 1997; Hoover & Dwivedi, 1998; Juffs, 1998, 2005; Juffs & Harrington, 1995; Williams et al., 2001). What is interesting about this study is that this linking was accomplished on-line by the L2 learners but not in exactly the same way as the native speakers. Specifically, the native speakers benefited from the purported additional gap position before the complementizer *that* in [6], as evidenced by their shorter reading times for this condi-

tion in comparison to a sentence that did not contain such a hypothesised intermediate gap position [8].

[8]   The nurse who the doctor's argument about the rude patient had angered __ is refusing to work late.

The native English speakers, therefore, were assumed to have mentally reactivated the moved constituent at this intermediate position, which 'refreshed' it in memory, and thus made it more available for integration upon meeting the subcategoriser in the input. None of the L2 learner groups showed this processing advantage, suggesting that such detailed underlying structural information might not be available to L2 learners in their on-line processing (see also Clahsen & Felser, 2006a, 2006b).

Further support for the suggestion that L2 learners might be less able to use underlying structural information comes from a cross-modal picture priming study (Felser & Roberts, 2007). In this task, the participants listen to a sentence [e.g., in 9], and at some strategic point during the auditory presentation, they are required to make a word-based discriminatory response to a picture target that is presented visually. The assumption, from the *priming* literature, is that responses to a pictured item are faster when the participant has been exposed to it, or some part of it, beforehand (Swinney, Onifer, Prather, & Hirshkowitz, 1979). In this study, the discrimination task was to decide, by pushing a button, whether the picture represented an object which was *alive* or *not alive.* In the study on which this was based (Roberts, Marinis, Felser, & Clahsen, 2007), high working memory span native speakers (both adults and children) were quicker in their response times (RTs) to a picture target of the fronted indirect object *the peacock* when it was presented at the position from which the constituent was originally extracted (its base position) following the direct object *the nice birthday present* [#1] than when the picture was presented at a position earlier in the sentence [#2]. Further to this, responses to the identical target picture of the peacock were also faster than those to a picture of a semantically unrelated target (a carrot) at this base position [#1]. This suggests that for native speakers, the fronted or extracted indirect object argument was mentally reactivated in on-line comprehension, but only at the structurally relevant position [#1].

[9]   John saw the peacock to which the small penguin gave the **#2** nice birthday present **#1** in the garden.

Felser & Roberts (2007) tested advanced Greek L2 learners of English, and found that they too were faster to respond to pictures of the identical target [peacock] than to unrelated picture targets [carrot], but their performance differed from the native speakers in the Roberts et al. (2007) study in that this advantage was in evidence irrespective of where in the sentence the target picture was presented (#1 and #2). Therefore, rather than showing *reactivation* of the fronted argument at the structurally relevant position, the L2 learners showed *maintained* activation of the moved element. That is,

they appeared to keep the item in memory, while they processed the sentence, until it was required for integration. In sum, this task probed the 'gap site' and found support for the idea that this type of underlying syntactic information might not be as available in L2 processing. Interestingly, even though working memory span affected the Roberts et al. native speakers' processing of these sentences, all the Greek L2 learners performed in the same way, irrespective of any differences in working memory.

These studies show that the properties of the first language did not affect the processing of *wh*-items in the L2, a finding which has been reported elsewhere (Juffs, 1998, 2005; Williams et al., 2001), and instead suggests that L2 processing may differ in qualitatively different ways from that of native speakers, at least when making use of structural information in on-line sentence processing. However, many of the sentences used in such studies are highly complex and the tasks often rather unnatural, and therefore the question arises as to whether such L1-L2 processing differences are observed in the on-line comprehension of much more simple and everyday dependencies, and when participants are tested using a more natural task.

In a recent study, using eye-tracking during reading, Roberts, Gullberg, and Indefrey (to appear) investigated whether L2 learners of Dutch would process texts containing subject pronouns in the same way as Dutch native speakers. Turkish learners of Dutch were compared to German L2 learners of Dutch in their processing of texts like [10], where native speakers prefer to co-refer the subject pronoun *hij* with the most recently mentioned referent *Peter* in the local, adverbial clause.

[10]   Peter en Hans zitten in het kantoor. Terwijl Peter$_i$ aan het werk is, eet hij$_i$ een boterham.
'Peter and Hans are in the office. While Peter is working, he is eating a sandwich.'

Dutch and German are similar in that subject pronouns are obligatory, whereas in Turkish they are optional, with their use relative to overt subject pronouns being governed by discourse-pragmatic factors. A direct translation of [10] into Turkish [11] shows that the subject pronoun in Turkish [*o = he*] cannot refer to the local referent Peter, but must refer to somebody other than this local referent, thus most readily co-refers with *Hans* in the previous discourse.

[11]   Peter ve Hans$_j$ ofiste oturuyorlar. Peter$_i$ çalışırken, o$_{*i/j}$ sandeviç yiyor.

Should a Turkish speaker wish to refer to the most recently mentioned (and thus most cognitively salient and accessible) referent, an overt pronoun would not be used. Roberts et al. (to appear) examined whether this L1 difference would have an effect on how the Turkish learners would process such texts with Dutch subject pronouns. The participants were required to read the texts and to answer a simple comprehension question and their eye-movements were recorded as they did so. Specifically, the authors asked whether the Turkish learners would prefer to co-refer a Dutch subject

pronoun with the disjoint referent (provided in the earlier discourse, *Hans* in [10]), as would most likely be the case with a subject pronoun in Turkish [11]. Interestingly, in their processing of the experimental items, it was not the Turkish L2 learners who differed from the other two groups, but rather it was the two L2 groups who patterned together. Specifically, there was no difference between the L2 learner groups' performance, despite the fact that German patterns like Dutch with regard to subject pronouns. Both groups found processing the subject pronoun more difficult in [10], in comparison to a condition where only one potential referent was grammatically available to co-refer with the pronoun, as shown in [12].

[12]   De Werknemers zitten in het kantoor. Terwijl Peter$_i$ aan het werk is, eet hij$_i$ een boterham.
'The workers are in the office. While Peter is working, he is eating a sandwich.'

This lack of L1 effect in the on-line processing results was rather surprising, given the results of the separate off-line comprehension task. Specifically, when asked for their preferred referent for the subject pronoun in [10], the German L2 learners patterned with the Dutch native speakers, overwhelmingly choosing the local, sentence-internal referent for the pronoun (*Peter* in [10]; Dutch 100%, German L2 learners, 91%), whereas the Turkish learners chose this referent only 55% of the time. Therefore, off-line, the learners' L1 came into play, but this did not occur in their on-line processing of items. These results raise the question of why the L2 learners, irrespective of their ultimate preferred resolution for the pronoun, found [10] more difficult to process than [12]. The authors point to the syntactic ambiguity of the pronoun in [10] which is absent in [12]. That is, there are two grammatically available referents (*Peter* and *Hans*) in [10], but only one (*Peter)* in [12], suggesting that when grammatical information cannot unambiguously inform the processor as in [10], L2 learners have more on-line processing difficulty. This is because they must co-ordinate both syntactic and discourse pragmatic information in order to arrive at their interpretation and this appears to be more difficult to achieve on-line, irrespective of the properties of the L1, and irrespective of their ultimate interpretation for the pronoun. Therefore, L2 learners' processing of complex syntactic dependencies may not be exactly native-like, although in many cases this may not affect ultimate comprehension. On-line, integrating information from different sources and making use of abstract structural information appears to be more difficult to achieve for L2 learners than for native speakers, irrespective of how typologically close the learners L1 is to the target language.

Conclusions

To summarize, I will return to each of the questions raised earlier in an attempt to bring the findings together to obtain a picture of how L2 learners might process the target language in real time.

How do L2 learners process the target language in comparison to native speakers?

It seems clear that like native speakers, L2 learners process the input incrementally, that is, they are able to integrate each new word into the current analysis in on-line comprehension, as the results of the garden-path studies show. Furthermore, like native speakers, lexical-semantic, thematic and plausibility information is put to use very rapidly and can effectively inform analyses, and affect commitment to and the recovery from misanalysis. The results from the above studies suggest that any differences between L2 learners and native speakers may lie in their use of structural information. Specifically, with ambiguity processing, L2 learners may not be as able to use syntactic information to base an analysis on, although this appears to be no problem with lexical-semantic information. In processing dependencies, like native speakers, L2 learners can integrate a moved argument with its subcategorising head in order to correctly interpret such sentences. However, underlying abstract structural information, like syntactic gaps, appears to be less available (see also Clahsen & Felser, 2006a, 2006b). Of course, the question arises as to whether L2 learners are ever able to become native-like in their ability to make use of syntactic information on-line. In the majority of the above studies, the participants were all intermediate to advanced L2 learners, having started learning the L2 in adulthood and so in order to address this question, much more research is needed with learners of different proficiency levels, perhaps comparing adult L2 learners with bilinguals, and/or child L2 learners.

Does the L1 influence L2 learners' moment-by-moment processing decisions?

Most of the results reported above suggest that the first language does not affect the on-line processing of the L2. Where differences between L2 learners and native speakers have been found, L1 transfer appears not to provide the explanation, as can be seen in the results of studies where L2 learners of completely different L1 backgrounds perform similarly (e.g., Marinis, et. al; Roberts, et al. to appear). Even more striking, though, are the results of studies which have shown that even where the learners first and second languages are similar, L2 processing differs (e.g., Papadopoulou & Clahsen, 2003). This suggests that at least at a certain level of proficiency, the L1 has an effect, but not in any specific way. Rather, the results suggest that the mere presence of more than one language may affect how the L2 is processed. That there may be such a 'general L2 processing effect' is strongly suggested by the results of much of the research reported above. In the majority of the studies, the L2 learners' (off-line) grammatical knowledge was target-like, and yet their on-line processing was not. Moreover, the Turkish L2 learners in the study by Roberts et al., (to appear) did not have target-like interpretations for subject pronouns, and yet performed like the German L2 learners (who did), with both groups processing the items differently from Dutch native speakers. Thus the presence of any other language irrespective of how similar or different it is from the target language, appears to influence L2 processing, at least when structural information must also be put to use. However, again, much more research is needed, in particular to see under what circumstances and at

what point on the proficiency continuum this L2 processing effect might continue to exert its influence.

What is the effect of individual factors such as level of proficiency, and/or the amount, type and age of exposure?

As stated above, if L2 learners differ from native speakers in their on-line processing, specific properties of their L1 may not always be the cause. The results of the studies discussed above offer evidence for this. However with regard to the potential influence of individual differences, the findings are less clear. This is most likely because the field of L2 processing is still in its infancy, and such potential influencing variables have yet to be systematically tested (rather they have thus far been 'controlled for'). The results of the Felser and Roberts (2007) show that working memory did not influence L2 processing (see also Juffs, 2005) even though this was the case for the children and adult native control groups on which the study was based. The potential effects of language proficiency are also not clear. For instance, Roberts (2003) found that proficiency did not affect the processing of ambiguous sentences at all, and it did not affect the processing complex syntactic dependencies in any qualitative way. However, it may be that such factors have a different effect, depending on the type of construction being processed. It should be noted, perhaps, that many of these language background variables are highly correlated; age of exposure, type and length of education, language proficiency, for instance, and so teasing them apart in an attempt to pinpoint their specific effects on real-time processing is likely to be rather problematic. Despite this, it would indeed be a worthwhile endeavour.

So, recent research is beginning to address a specific concern that has been raised by L2 acquisition researchers in the past; that in order to obtain a more detailed picture of what a learner *knows* of the target language, it is important to investigate L2 learners' and bilinguals' real-time processing as well as their off-line comprehension and production (Carroll, 2001; Chaudron, 1985; Truscott & Sharwood Smith, 2004; Valian, 1990).

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