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How native-like is non-native language processing?

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Following several decades of research on native language (L1) processing, psycholinguists have more recently begun to investigate how non-native language (L2) speakers comprehend and process language in real time. Regarding the traditional assumption that L2 learners have 'difficulty with grammar', this new research has revealed some unexpected similarities and differences between L1 and L2 processing. Specifically, it appears that L2 processing can become native-like in some linguistic subdomains (including certain aspects of grammar) but that L1 and L2 processing differences persist in the domain of complex syntax, even in highly proficient L2 speakers. Thus, more subtle linguistic distinctions seem to be required to understand the nature of non-native language processing.

Introduction

For most people, learning a foreign language in adolescence or adulthood proves to be a difficult task, which is generally less successful, more affected by factors such as motivation and aptitude, and which leads to less uniform linguistic systems than is the case when learning one's native language in childhood. Previous language acquisition research has relied mainly on speech production and other offline data to describe the linguistic knowledge of non-native speakers and how it develops over time [1]. Even though acquiring a foreign language also presupposes the ability to analyze and process the linguistic input in appropriate ways, non-native language processing has long been the subject of much speculation and little empirical investigation. This has changed in recent years because researchers from different disciplines have begun to investigate non-native language processing using experimental psycholinguistic techniques such as response-time measures, eye-movement monitoring, brain imaging and event-related brain potentials (ERPs). This line of research has led to a substantial number of empirical findings on non-native reading and listening, and new theoretical proposals as to how and why native and non-native language processing differ [2–7]. Traditionally, it has been assumed that L2 learners have more difficulty with grammar than with the lexicon [8]. However, recent research has shown that this distinction is too broad and that even 'late' learners who acquired a second language around or after puberty can achieve native-like processing in some domains of grammar. However, the processing of complex syntax by adult learners continues to be non-native-like, even after many years of L2 usage and exposure.

This article reviews recent results from behavioral and physiological studies of language processing in late L2 speakers. Our focus is on grammatical processing (or 'parsing'), which refers to the construction of structural representations for sentences, phrases and morphologically complex words in real-time language comprehension and production. Our main aim is to show that distinguishing between different types of grammatical phenomena leads to a better understanding of the nature of L2 processing difficulties.

Current opinions differ as to how L1 and L2 processing differences can be explained. Four main factors have been proposed: a lack of relevant grammatical knowledge, influence from the L1 of the learner, cognitive resource limitations and maturational changes during adolescence. The contribution of each of these factors will be examined below.

Limitations of the L2 grammar

Human language grammars can be conceived of as systems of combinatorial rules that are constrained by principles specifying the hierarchical structure of words, phrases and sentences. Linguistic research has shown that the acquisition of grammar by late learners is typically less successful and produces less uniform, and perhaps even fundamentally different, grammatical systems than L1 acquisition [1,9]. There is evidence that the rule systems developed by late L2 learners do not necessarily conform to the principles that constrain native grammars [9–11]. Assuming that sufficiently rich, implicit grammatical knowledge is a prerequisite for successful processing, nontarget-like L2 grammars could well give rise to non-native-like processing performance, even in learners who otherwise exhibit a high degree of proficiency as measured by general proficiency tests, offline grammar tasks or self-ratings.

We suggest that the linguistic distinction (common to many theories of grammar) between local dependencies, typically involving adjacent words or constituents, and nonlocal dependencies (Box 1) provides a way of characterizing similarities and differences between L1 and L2 grammatical processing. Evidence from several experimental studies indicates that late L2 learners can achieve native-like processing not only in the domain of lexical semantics during sentence comprehension [12–15], but also in the processing of grammatical relationships, such as gender concord within the noun phrase [16] or subject–verb agreement [12], that involve local dependencies. However, even

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Box 1. Nonlocal syntactic dependencies

Nonlocal dependencies arise, for example, in *wh*-questions such as in Figure I of this box, example (a), in which the *wh*-phrase has been fronted creating a long-distance dependency spanning three clauses. To interpret this sentence correctly, 'which book' needs to be linked to its lexical subcategorizer 'borrowed'. Nonlocal dependencies are subject to configurationally defined constraints. Simply replacing the auxiliary 'had' in example (a) by the pronoun 'who' in example (b), for instance, precludes the formation of a nonlocal dependency, a restriction of which native speakers are implicitly aware [67].

Other types of nonlocal dependency include those involving anaphoric elements such as reflexives or pronouns, and many other constructions displaying noncanonical word order. Determining the correct antecedent for reflexive pronouns such as 'herself' in sentences such as example (c) or (d), for instance, presupposes the ability to compute hierarchical phrase structure representations. Whereas in example (c), the reflexive pronoun 'herself' can only be interpreted as referring back to the linearly closer potential antecedent 'Alice' but not to the more distant 'Jane', the situation is the reverse in example (d), even though linear precedence relations are the same. Rather, it is the hierarchical structural position of 'Alice' and 'Jane' relative to 'herself' that determines which of the two can (or, indeed, must) enter into a coreference relationship with the reflexive.

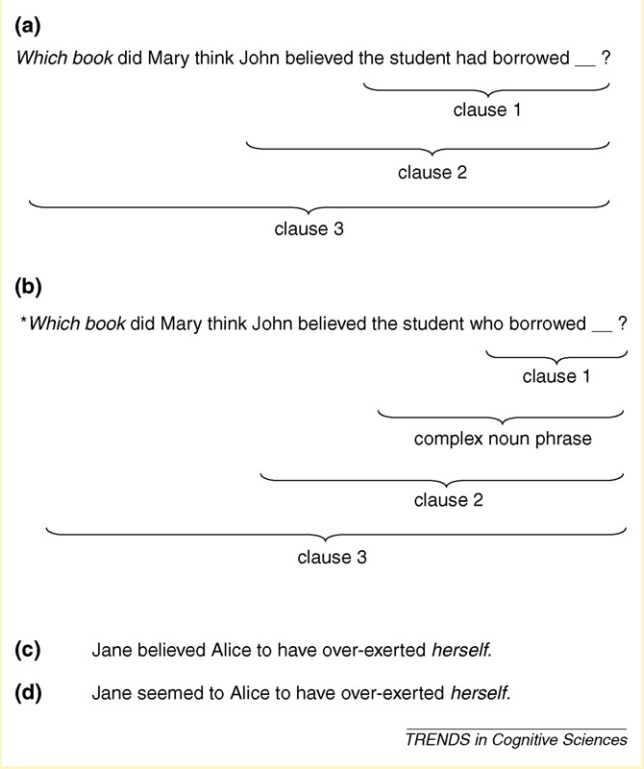

Figure I. Nonlocal syntactic dependencies in *wh*-questions and in sentences that contain reflexive anaphors. The asterisk in example (b) indicates ungrammaticality.

highly proficient learners have been found to process nonlocal dependencies differently from native speakers [17–19] (Box 2). Moreover, the strategies of L2 learners for resolving ambiguities in complex sentences were found to be affected by lexical-semantic information in the same way as in native speakers but less so by hierarchical constituent structure [20,21].

One attempt to account for these findings is the shallow structure hypothesis (SSH) [5,22]. Psycholinguists have argued that sentence interpretation in native speakers involves two different processing routes: full parsing, which provides a fully specified syntactic representation for an incoming string of words, and shallow parsing, which provides a less detailed representation based on lexical-semantic information, associative patterns and other surface cues to interpretation [23–25]. On the assumption that full parsing is fed by the grammar, the SSH claims that the L2 grammar does not provide the type of syntactic information required to process nonlocal grammatical phenomena in native-like ways. As a result, shallow parsing predominates in L2 processing, even though the basic architecture of the processing system is the same in the L1 and L2. Specifically, sentences for which full parsing yields complex hierarchical structures including abstract elements (e.g. syntactic gaps; Box 2) will typically involve shallow parsing in the L2, with greater reliance on semantic, associative and surface information than on syntactic cues to interpretation. However, word-level processing and morphosyntactic feature matching between adjacent or locally related words might be more easily mastered as grammatical proficiency increases and can eventually become native-like. Clearly, the SSH requires further testing and elaboration. In particular, it remains to be seen whether structural processing in a late-learnt L2 can ever become fully native-like. Hierarchically complex structures and nonlocal dependencies provide a useful testing ground for examining this question.

An additional factor likely to affect both L2 grammatical development and processing is transfer from the native language, given that late L2 learners have fully acquired their L1 and have had substantial prior experience in processing their native language before they begin to learn a non-native language.

The role of L1 transfer

Evidence for L1 transfer has frequently been reported in studies using offline tasks such as questionnaires, agent identification or production priming [6,26,27]. However, the problem with such tasks is that they do not necessarily reveal much about the automatic processes involved in real-time language processing and are amenable to later (perhaps conscious) processes after a sentence or word has been processed. Yet evidence from online experiments suggests that L1 transfer effects are in fact more limited than one might expect.

There is ample evidence that phonological, orthographic, morpholexical and lexical-semantic properties of the L1 affect L2 processing [28–33]. English L2 learners of French, for example, find sentences containing verbs such as 'obey' (which are intransitive in French but optionally transitive in English) more difficult to process than sentences containing verbs that are intransitive in both languages [28]. In addition, processing agentive nouns ending in *-er* in L2 English seems automatically to activate the masculine gender features associated with the German agentive suffix *-er* in German-speaking learners [31]. With regard to morphosyntactic transfer in local grammatical domains, the evidence is mixed. Some studies suggest that such properties do transfer in L2 processing [16,34], whereas others indicate that this is not the case [35,36] (M. Sato and C. Felser, unpublished).

Box 2. L2 processing of *wh*-dependencies

Results from L1 processing studies have shown that native speakers mentally reactivate fronted constituents at structurally defined 'gap' sites, even if these do not directly follow the subcategorizing verb [68,69]. Results from a crossmodal priming experiment using sentences containing indirect object gaps such as (i) showed that, unlike native speakers, proficient Greek-speaking learners of English did not reactivate the fronted constituent 'to which' (referring to 'the peacock') at the configurationally determined gap position following the direct object 'the birthday present', even though the structure of the Greek equivalent of (i) is parallel to English [17].

(i) John saw the peacock *to which* the small penguin gave the nice birthday present ___ in the garden last weekend.

Languages differ as to whether or not they require English-type *wh*-fronting in, for example, question or relative clause formation. A self-paced reading study investigated how L2 learners from different language backgrounds process complex *wh*-dependencies such as in (ii) and (iii) [19].

(ii) The nurse who the doctor argued that the rude patient had angered is refusing to work late.

(iii) The nurse who the doctor's argument about the rude patient had angered is refusing to work late.

The reading profiles of the learners differed from those of the native speakers, in that the learners were unaffected by the availability of an additional ('intermediate') gap in sentences such as (ii). The shorter reading times of native speakers on the segment containing the subcategorizing verb 'angered' in (ii) than in (iii) indicated that they had posited an additional gap at the intervening clause boundary – signaled by the function word 'that' in (ii) – effectively breaking up the long dependency into two shorter ones, as illustrated in Figure Ia of this box [19,69]. Cyclic reactivation of the filler in the processing of native speakers thus facilitated integration with its lexical subcategorizer 'angered' later on. By contrast, the L2 learners failed to postulate intermediate gaps, regardless of whether or not English-type *wh*-fronting was instantiated in their L1. Instead, they appeared to link the *wh*-filler 'who' (= 'the nurse') directly to the licensing predicate, as shown in Figure Ib of this box.

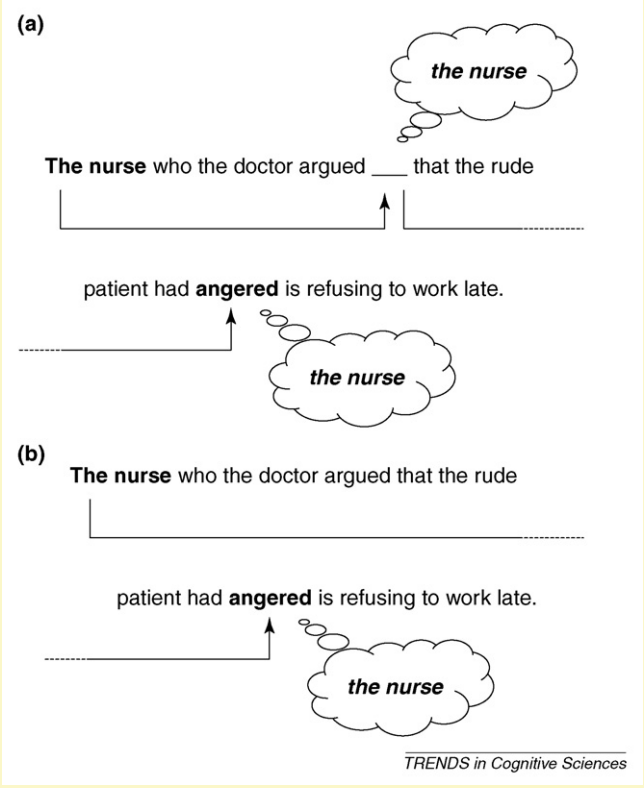

Figure I. Reactivation of dislocated constituents during processing. **(a)** Structurally mediated filler reactivation at gap sites in native speakers. **(b)** Lexically mediated filler integration in L2 processing.

Regarding the transfer of L1-specific sentence processing preferences, the phenomenon that has been studied in most detail is relative clause ambiguity resolution in sentences such as 'Someone shot the servant of the actress *who was standing on the balcony*'. Here the (italicized) relative clause can either be interpreted to modify the second noun phrase (implying that the actress was on the balcony), the option typically preferred by native speakers of English, or the first one (the servant), the option preferred by L1 speakers of, for example, French, Spanish, German or Greek. A series of reading-time experiments investigating the attachment preferences of proficient L2 learners revealed remarkably similar, non-native-like response patterns in different target languages and across learner groups from typologically different language backgrounds but no evidence of L1 transfer [20,21]. Although data from an eye-movement study revealed a pattern suggestive of L1 transfer in beginning English-speaking learners of French [37], there is otherwise little indication that non-native comprehenders apply their L1 ambiguity resolution preferences when processing complex sentences in their L2.

Few online studies have examined the potential influence of more abstract structural L1 and L2 differences – such as those involving nonlocal syntactic dependencies – but current evidence suggests that these have no effect on L2 processing [19,38]. The findings reported in Box 2 suggest that abstract syntactic properties such as the availability of *wh*-fronting in the L1 do not influence the processing of *wh*-dependencies in the L2.

In sum, whereas L1 influence of phonological and lexical properties is well attested, nonlocal dependencies do not seem to be susceptible to transfer effects in L2 processing. The absence of transfer effects in this domain could be due to a mapping incompatibility between the L1 and L2 representations of learners – for example, if the latter are 'shallow' in the sense described earlier.

Divergent processing of complex sentences might also result from L2 processing being more demanding in terms of general cognitive resources than processing one's native language, resulting in less automatic processing [39], as discussed below.

Cognitive resource limitations

The question of whether L2 grammatical processing is less automatic than L1 processing has primarily been examined in studies using ERPs, a technique that offers a detailed record of the time course of language processing. In native speakers, ERP signatures associated with structural language processing include an early, left-lateralized anterior negativity (LAN) and a later posterior positivity (P600) peaking at ~600 ms after stimulus onset and usually distributed centroparietally [40]. A negative-going wave peaking at around 400 ms after stimulus onset is thought to index lexical-semantic processing [41]. ERP

studies examining lexical-semantic processing during sentence comprehension obtained N400 effects for L2 learners that were largely similar to those seen in native speakers, albeit sometimes with delayed latencies and/or reduced amplitudes [3,13,15,42,43]. For morphologically complex words, L2 learners produced a biphasic ERP pattern in domains in which they were highly proficient, with the same early anterior negativity as was seen in the native speaker controls [44]. As illustrated in Figure 1, incorrect participles elicited an anterior negativity followed by a P600, whereas incorrect plural forms only produced a P600. This contrast corresponded to proficiency differences, as revealed by an elicited production task in which the L2 participants performed considerably worse on plurals than on participles. These findings suggest that L2 processing of morphologically complex words can be native-like and can shift towards automatization in highly proficient L2 learners.

Most ERP studies of sentence processing in non-native speakers have obtained P600 effects (sometimes with delayed peak latencies) but not the early anterior negativity that was observed in native speakers for the same materials [3]. However, native-like LAN effects are occasionally seen in learners at or near the top end of the proficiency scale in response to local grammatical violations. Violations of subject–verb agreement elicited a LAN, but no P600, in highly proficient Japanese-speaking learners in L2 English [12], and in a study using an artificial language paradigm, word category violations elicited both a LAN and a P600 [45]. By contrast, in a similar study using a 'miniature' version of Japanese, in which adults were trained to a level of perfection at which they produced hardly any errors, the learners produced a P600 in response to word category and case violations, but no LAN [46].

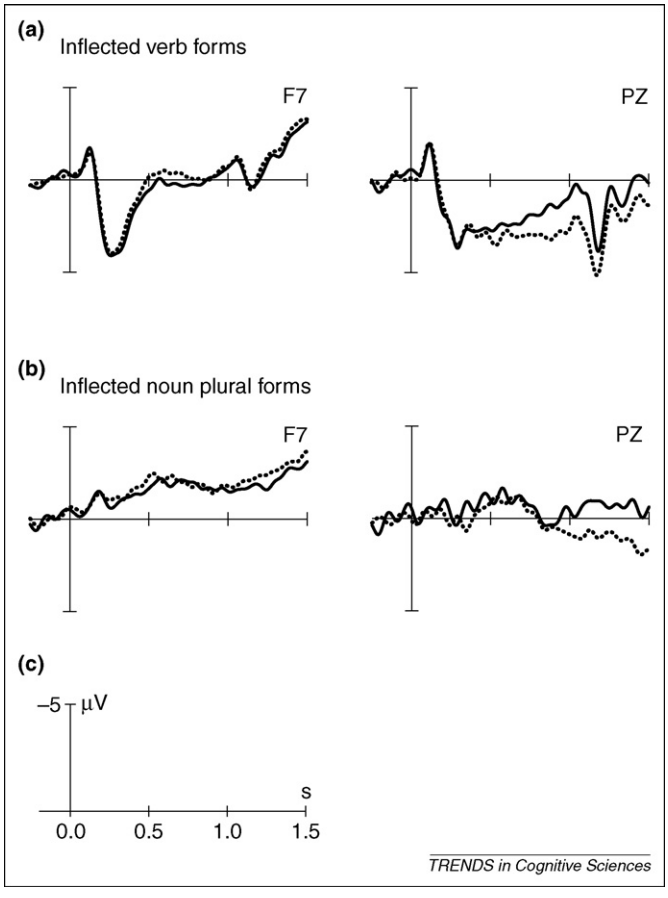

Figure 1. ERPs for left-frontal (F7) and centroparietal (PZ) electrode sites for correct (straight line) and incorrect (dotted line) inflected word forms. **(a)** Participle forms (*gelaufen* 'run' versus **gelauft*). **(b)** Noun plural forms (*Enten* 'ducks' versus **Entes*). **(c)** The scale bars refer to all four panels. Modified, with permission, from Ref. [44].

Although the functional significance of the LAN and P600 for L1 processing is still controversial [47], some researchers have interpreted these two components as reflecting distinct stages of processing, with the early negativity indexing automatic first-pass parsing processes and the late positivity tapping more controlled processes of reanalysis and repair [40]. Given this interpretation, the absence of a LAN in the majority of L2 studies suggests that automaticity is indeed reduced in L2 sentence processing, although there is some indication that the degree of automaticity involved in the processing of local grammatical dependencies might increase with L2 proficiency. However, it remains to be seen whether L2 processing of sentences involving complex hierarchical structure can ever become fully automatized (as indicated, for example, by LAN effects).

As regards the possible causes of reduced automaticity in L2 processing, it is conceivable that having to identify words and phrases in an L2 incurs an additional drain on working memory resources [48]. The response times of L2 learners in behavioral experiments are generally slower than those of native speakers, and results from neuroimaging studies have shown increased cortical activation for structurally difficult sentences in the L2 [49], indicating that L2 comprehension requires greater computational effort than L1 comprehension. Assuming that the processing of nonlocal dependencies makes greater demands on working memory [50], the difficulties of learners in this domain might result from a shortage of working memory resources during non-native processing, rather than from insufficient grammatical knowledge. However, although efficient phonological working memory has been found to correlate with superior skills in an L2 [51–53], the few (behavioral) studies that have investigated the role of individual working memory differences in L2 sentence processing have reported small or no working memory effects [17,54,55]. Clearly, the possible influence of cognitive resource limitations on L2 processing requires further investigation. Alternatively, or in addition to resource limitations, reduced automaticity and other differences between L1 and adult L2 processing might result from maturational changes of the neural systems involved in language representation and use.

Maturational constraints

The acquisition of grammar has often been claimed to be subject to 'critical period' effects [56], and it is conceivable that developmental changes during childhood or around puberty are responsible for the observed differences between L1 and L2 grammatical processing [14,57]. A specific proposal along these lines is the declarative–procedural model, which claims that due to maturational

factors, the procedural memory system is less involved in L2 than in L1 processing [57,58].

This proposal is based on the distinction between two brain memory systems relevant for language processing: a declarative system, which subserves the storage of memorized words and phrases and is rooted in a network of specific brain structures, including medial temporal and prefrontal cortical regions, and a procedural system, which is involved in processing combinatorial rules of language and which depends on a network including frontal–basal ganglia circuits and the inferior frontal gyrus (BA44, or Broca's area) [57]. Late L2 learners are claimed to over-rely on the declarative system, even for functions such as grammatical processing, which in native speakers depends upon the procedural system. The over-reliance on the declarative system in L2 processing is attributed to maturational changes that occur during childhood and adolescence (e.g. increasing estrogen levels in both genders), leading to attenuation of the procedural and enhancement of the declarative system [58]. As a result of these changes, late L2 learners predominantly use their declarative memory system to process complex linguistic forms and phrases that normally involve combinatorial processing in native speakers. Assuming that experience and practice help learners to develop procedural skills in the L2, grammatical processing in highly proficient L2 learners can eventually become native-like.

Several findings are consistent with these claims. Behavioral experiments revealed that L2 readers or listeners have no difficulty in accessing and evaluating lexical-semantic or plausibility information during sentence processing [20,21,38]. ERP studies of lexical-semantic processing during sentence comprehension consistently obtained N400 effects in both native and non-native speakers [3,15,42,43], and neuroimaging studies using lexical tasks have elicited the same levels of brain activation in the L2 and the L1 in similar cortical areas [59]. These findings suggest that the declarative memory system is fully operational in L2 learners. However, L2 learners were found to underuse syntactic information when interpreting ambiguous sentences and during the processing of sentences containing long-distance dependencies [17–21]. Most ERP studies of L2 grammatical processing have failed to elicit LAN effects of the type seen in native speakers [3], and brain imaging results showed that while listening to stories in their L1 and their L2, learners with a moderate command of the L2 recruited a large network of left hemisphere areas (including frontal regions) in their L1 and a more reduced symmetrical network within the temporal gyri for the L2 [60]. Interestingly, these differing cortical L1 and L2 responses disappeared in high-proficiency learners [61]. Results from an artificial language-learning study indicate that the engagement of Broca's area in grammar acquisition increased with proficiency, accompanied by a corresponding decrease in activation in medial temporal regions [62], and a recent functional magnetic resonance imaging study of sentence production revealed reduced activation of the basal ganglia in less proficient L2 learners [63]. Taken together, these findings are indeed compatible with a reduced availability of the procedural system in L2 acquisition and processing, with the possibility of procedural memory structures becoming more involved at higher proficiency levels.

However, a high degree of proficiency in the L2 does not necessarily lead to native-like processing. Even learners who were indistinguishable from L1 speakers in offline tasks, or who went through long periods of immersion, failed to show indications of native-like procedural processing of morphosyntactic phenomena [17–19,46,64]. These results indicate that experience and practice might not be enough to develop native-like grammatical processing skills in an L2, and brain imaging results suggest that proficiency differences affect L2 semantics more than grammar [14]. Moreover, in contrast to the claim that L2 learners over-rely on the declarative memory system, the study reported in Box 3 found higher levels of activation in frontal brain structures (including BA44), indicative of procedural processing in L2 learners who scored significantly worse than native speakers on an offline proficiency measure. Finally, the L1 and L2 localization issue is still far from settled because the results from several brain imaging studies point towards overlapping cortical regions being involved in both L1 and L2 processing, including Broca's area [65,66], which is difficult to reconcile with the localization claims made by the declarative–procedural model.

Summarizing, even though grammatical processing appears to be affected by maturational constraints [14,15], the specific claims of the declarative–procedural model only provide a partial account of the observed L1 and L2 processing differences.

Concluding remarks

This survey of behavioral and physiological studies shows that the traditional assumption that late L2 learners have problems with grammar but not with semantics needs to be refined, and that L1 and L2 processing differences are more restricted than was previously thought. Learners appear to be capable, in principle, of processing grammatical phenomena involving locally related constituents in a native-like fashion but not those involving structurally complex phenomena such as nonlocal dependencies, indicating that L2 learners do not have problems with all aspects of grammar but with the real-time computation of complex hierarchical representations.

However, given the small number of L2 studies using online techniques, several questions remain for future research (Box 4). We need to determine whether the available results generalize to linguistic phenomena and to L1 and L2 combinations other than those that have been examined thus far. Moreover, little is known about how L2 processing abilities develop over time, or about online processes involved in L2 production. Models of non-native language processing also need to include a time-course dimension specifying at which points in time different sources of information become available during processing. Finally, to determine the upper limits of L2 grammatical processing ability, more research is needed, focusing on complex structural phenomena

Box 3. Brain structures involved in L2 processing

Two versions of incorrect passive sentences of German, one containing a semantic violation (= inappropriate thematic role) and one containing a syntactic violation (= incorrect prepositional phrase) were compared with corresponding correct sentences. Eighteen native speakers and 14 L2 learners provided grammaticality judgments to auditorily presented sentences while they were in the fMRI scanner [70].

The judgment scores of the L2 learners were significantly lower than those of the L1 speakers, specifically for the syntactic violation condition, indicating reduced L2 proficiency in this domain. The direct contrast maps in Figure I of this box show greater levels of activation for L2 learners than for native speakers in left frontal areas (IFG, including the superior portion of BA44) for both correct sentences and syntactic violations. In the semantic violation condition, L1 and L2 speakers showed the same levels of activation in the IFG. Temporal lobe areas (STG) showed greater levels of activation for L1 than for L2 speakers.

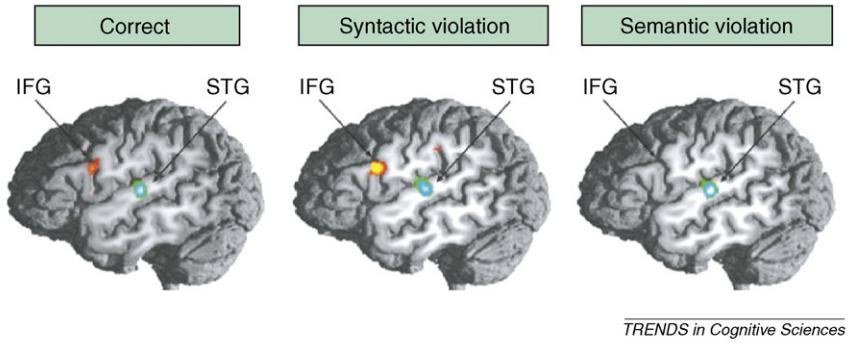

Figure I. Direct contrast maps of native versus non-native speakers of German for correct, syntactically anomalous and semantically anomalous sentences. Colors show statistically significant differences between native and non-native speakers in two cortical regions, the left superior temporal gyrus (STG) and the left inferior frontal gyrus (IFG). Increased activation for L2 speakers is shown in red and yellow, and increased activation for L1 speakers in green. Modified, with permission, from Ref. [70].

Box 4. Questions for future research

- How do L2 learners process complex grammatical phenomena other than those that have been examined thus far?
- Do previous findings on L2 grammatical processing generalize to L1 and L2 combinations that have not yet been tested?
- How does the typological distance between the L1 and L2 influence L2 processing?
- How do L2 grammatical processing abilities change over time?
- How does grammatical processing differ between early and late L2 learners?
- Can grammatical processing become fully native-like in so-called near-native speakers, who show a degree of L2 mastery and fluency that makes them virtually indistinguishable from native speakers?
- How does the time course of language processing differ between native and non-native speakers?
- What are the online processes involved in L2 production?

and examining learners at or near the top end of the proficiency scale.

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