ANNUAL REVIEWS

Annual Review of Linguistics

Second Language Sentence Processing

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Annu. Rev. Linguist. 2022. 8:235–56

The *Annual Review of Linguistics* is online at linguistics.annualreviews.org

https://doi.org/10.1146/annurev-linguistics-030821-054113

Keywords

second language, bilingualism, sentence comprehension, parsing, grammar

Abstract

Second language (L2) sentence processing research studies how adult L2 learners understand sentences in real time. I review how L2 sentence processing differs from monolingual first-language (L1) processing and outline major findings and approaches. Three interacting factors appear to mandate L1–L2 differences: (*a*) capacity restrictions in the ability to integrate information in an L2; (*b*) L1–L2 differences in the weighting of cues, the timing of their application, and the efficiency of their retrieval; and (*c*) variation in the utility functions of predictive processing. Against this backdrop, I outline a novel paradigm of interlanguage processing, which examines bilingual features of L2 processing, such as bilingual language systems, nonselective access to all grammars, and processing to learn an L2. Interlanguage processing goes beyond the traditional framing of L2 sentence processing as an incomplete form of monolingual processing and reconnects the field with current approaches to grammar acquisition and the bilingual mental lexicon.

1. INTRODUCTION

When comprehending sentences in real time, language users rapidly integrate incoming input to project syntactic relations and structure and map these to interpretation. Research in second language (L2) sentence processing investigates how non-native L2 users, typically adult L2 learners, who have learned an L2 later in life, differ in real-time comprehension from monolingual first-language (L1) speakers who acquired a language from birth onward. On top of providing insights into how the language processing system handles an additional, typically less-used language, L2 processing research explores the extent to which differences in language processing, rather than in linguistic knowledge, between L1 and L2 speakers can account for characteristic features of late (second) language acquisition, such as slow and variable development as well as non-native-like ultimate attainment (Bley-Vroman 1988). Broadly speaking, L2 sentence processing can differ from L1 processing in four ways.

- First, effects of the L1 could affect L2 processing in that L2 learners transfer processing strategies based on the L1 or recruit L1-based grammatical knowledge when parsing the L2, which could lead to partially different processing profiles compared to those of monolinguals.
- Second, adult L2 learners process the L2 in a noisier cognitive architecture, which may lead to slower, more effortful, and more error-prone processing. In particular, parsing a less-used L2 places larger demands on a limited capacity parser so that restrictions in working memory, slower processing speed, and a reduced ability to integrate different information types in real time may compromise the ability of L2 learners to effect complete parses.
- Third, L2 processing could be qualitatively different from L1 processing in that L2 learners weight processing constraints differently or rely on less-detailed processing heuristics.
- Fourth, L2 processing may be fundamentally distinct from L1 parsing in that maturational constraints render the grammatical processing system used by native speakers inaccessible and force late L2 learners to recruit explicit knowledge in sentence comprehension.

Although obviously not mutually exclusive, these options have given rise to a number of approaches to L2 sentence processing that build on models familiar from research on monolingual sentence processing.

Capitalizing on the first two potential differences, identity-oriented approaches posit that the linguistic representations and the relevant neurocognitive systems are fully engaged by L1 and L2 users alike, and that L1–L2 differences reduce to performance differences or effects from the L1. Specifically, L2 users may not fully compute and complete all processing steps because of the generally higher cognitive demands of processing an L2 (e.g., Hopp 2010, McDonald 2006), the more costly processing for particular types of information at linguistic interfaces (the Interface Hypothesis; Sorace 2011), a reduced capacity to recruit predictive mechanisms in processing [the Reduced Ability to Generate Expectations (RAGE) Hypothesis; Grüter et al. 2017, Kaan 2014], and/or cross-linguistic interference and slower retrieval from the bilingual mental lexicon (the Lexical Bottleneck Hypothesis; Hopp 2018). In appealing to the additional demands of processing a non-native language, this set of identity-oriented models refers to capacity models of language processing (e.g., Just & Carpenter 1992).

In contrast, difference-oriented accounts focus on the final two options and claim that L2 processing differs from L1 processing with respect to the detail of linguistic representations used or the neurocognitive (memory) systems recruited during real-time comprehension. For instance, the Shallow Structure Hypothesis (Clahsen & Felser 2006, 2018) refers to dual-pathway models of monolingual sentence processing, such as Good-Enough processing (Ferreira & Patson 2007), and argues that L2 users predominantly rely on nongrammatical processing heuristics instead of engaging in structure-based syntactic processing. Other approaches hold that L2 learners are more susceptible to interfering cues than monolinguals are (Cunnings 2017), as captured by cue-based retrieval models of sentence processing (e.g., McElree 2000). An even stronger position is espoused by the Declarative/Procedural Model, which claims that adult L2 learners process syntactic dependencies and nonlocal agreement in different neurocognitive systems using declarative rather than procedural memory (Ullman 2016).

To explore the scope of L1–L2 differences, in this review I survey the main strands of research in L2 sentence processing, focusing on grammatical phenomena for which adult L2 processing has been found to differ from L1 processing. Across these areas, L2 sentence processing displays all the hallmarks of L1 processing. Against this backdrop, I argue that the predominant concern with explaining differences between L1 and L2 processing should be abandoned—not least because it invariably conceptualizes L2 processing as a deficient or deviant form of monolingual processing. In doing so, it glosses over "bilingual" features of L2 processing, such as the constant coactivation of two languages. Reorienting L2 processing to focus on these bilingual features will allow the field to address fundamental architectural questions about relations between grammar and the parser and will provide insights into the role of language processing for learning. With these questions in mind, I suggest widening the perspective toward interlanguage processing, and I sketch some promising lines of future inquiry in broad brushstrokes.

2. TOPICS AND MODELS OF L2 SENTENCE PROCESSING

In real-time sentence comprehension, monolingual speakers rapidly integrate bottom-up information extracted from linguistic items encountered in the speech stream or text input with top-down contextual information or world knowledge. This integration has been modeled as the interaction of (*a*) universal and language-particular linguistic constraints, (*b*) processing constraints reflecting the architecture of the parser including restrictions in cognitive capacities (e.g., working memory), and (*c*) experience-based constraints indexing language use (for review, see MacDonald & Hsiao 2018, van Gompel 2013).

Linguistic research on L2 sentence processing predominantly investigates how adult L2 learners may differ from monolingual natives in their use of (*a*) linguistic and (*b*) processing constraints, while processing differences owing to (*c*) experiential factors have mainly been explored within usage-based frameworks (for review, see Sagarra 2022). With an emphasis on behavioral research, I review three core areas in research on L2 sentence processing: the processing of temporary syntactic ambiguities, the recruitment of structure-based syntactic constraints, and the use of morphosyntactic information in agreement relations, in particular for predictive processing (for a review of neurophysiological L2 research on sentence processing, see van Hell & Tokowicz 2010).

2.1. Temporary Syntactic Ambiguities, Reanalysis, and the Integration of Information

Like L1 adults, L2 learners incrementally integrate each incoming element into a partial and unfolding interpretation when comprehending sentences in their L2. As a consequence, L2 sentence comprehension is also subject to misanalyses and reanalyses in the processing of temporarily ambiguous sentences, such as object–subject ambiguities in sentences like *While the band played the song pleased all the customers*. L2 readers are led down the garden path in initially interpreting the postverbal noun phrase (i.e., *the song*) as an object. Subsequently, they show slowdowns on the main clause verb, indicating that they engage in syntactic reanalysis of the noun phrase as being the subject of the main clause (Juffs & Harrington 1996). These effects hold irrespective of L1 differences in word order (Juffs 2004), suggesting that L2 learners apply grammatical L2 properties to guide parsing. Moreover, L2 speakers use other types of L2 information for the resolution of syntactic ambiguities, such as verb transitivity (Hopp 2015a), frequency information of verbal complements, so-called verb biases (e.g., Dussias & Cramer Scaltz 2008, Lee et al. 2013), plausibility (e.g., Hopp 2015a, Roberts & Felser 2011, Williams et al. 2001), discourse context (e.g., Pan & Felser 2011), and prosody (e.g., Dekydtspotter et al. 2008, Nickels et al. 2013). In these respects, the L1 and L2 processing of temporary ambiguities appear to be broadly comparable.

At the same time, L2 readers struggle with reanalysis more than native speakers do (Roberts & Felser 2011). For instance, Jacob & Felser (2016) tested L1 German learners of English on sentences like example 1 that either marked clause boundaries using commas or lacked commas, allowing for an initial object reading of the postverbal noun:

(1) While the gentleman was eating(,) the burgers were still being reheated in the microwave.

In example 1, the auxiliary in the main clause (*were*) forces reanalysis of the noun phrase (*the burgers*) to a subject reading. However, both native controls and the L2 group continued to read the following regions more slowly in the garden-path conditions compared to the comma conditions; this result suggests that the syntactic disambiguation did not erase the initial analysis of *the burgers* as an object, creating semantic persistence. In this and other studies, L2 learners often demonstrated larger and longer-lasting semantic persistence than did monolinguals (Pozzan & Trueswell 2016, yet see Fujita & Cunnings 2020). To pinpoint the nature of reanalysis difficulty, Şafak & Hopp (2021) manipulated the strength of the initial garden path in terms of the verb bias toward an object reading of the postverbal noun. Both English monolinguals and L1 Turkish and L1 German advanced L2 learners showed different strengths of garden-pathing according to verb bias. Unlike in English monolinguals, though, garden-path strength did not modulate later semantic persistence in advanced L2 readers, which suggests that the L2 learners could not integrate earlier verb-bias information when recovering from garden paths. Such a reduced facility to integrate different types of information for reanalysis in real-time processing is characteristic even of highly proficient L2 learners.

For instance, L2 learners do not reliably use case marking for word order revisions in processing flexible word order languages (e.g., Hopp 2006, Jackson 2008), and they recruit plausibility information more slowly for reanalysis than natives do (Dussias & Piñar 2010, Jessen & Felser 2019). Importantly, individual differences among L2 learners affect the extent of how reliably L2 learners integrate different information types in L2 sentence comprehension. For one thing, L1–L2 similarity in the type of information that needs to be integrated facilitates reanalysis in the L2 in that, for instance, L2 learners whose L1 has case marking outperform L2 learners whose L1s do not mark case (Frenck-Mestre et al. 2019, Hopp 2010). For another, learners are more native-like in the processing of temporary ambiguities at higher L2 proficiency (Hopp 2010, Hoshino et al. 2010), as well as if they have larger cognitive resources in working memory (Dussias & Piñar 2010), faster processing speeds (Kaan et al. 2015), and/or greater automaticity in lower-level linguistic processing, such as lexical access (Hopp 2014). Conversely, L1 speakers sometimes show integration difficulties similar to those of L2 learners when processing the L1 under adverse conditions, for instance, at higher speeds or in noisy conditions (e.g., Hopp 2010, López Prego & Gabriele 2014, McDonald 2006). Further, sentence processing in L2 learners often resembles processing in other language learners, such as child L1 learners (Trueswell et al. 1999), or in users with restricted resources, such as people with aphasia (Haarman et al. 1997) or L1 adults with lower working-memory capacities (e.g., Havik et al. 2009).

These parallels, including studies demonstrating native-like processing for some L2 learners, suggest a large degree of identity or continuity between L1 and L2 processing. However, the inherently greater load in processing a less-used L2 compared to an L1 may lead L2 learners to adopt economy principles in parsing that minimize dependency length (e.g., Gibson 1998) and curtail the use of multiple information types (e.g., McRae & Matsuki 2013), so that L2 learners do not always effect full parses.

In all, then, capacity limitations when processing a late-learned L2 can explain delayed or attenuated reanalysis or failures to integrate different information types during real-time comprehension of the L2. At the same time, not all information types are equally hard to integrate in L2 sentence processing: L2 learners easily accommodate lexical-semantic or discourse information in resolving temporary ambiguities, sometimes even to larger degrees than native speakers do (Jackson & Roberts 2010, Pan & Felser 2011). In contrast, the integration of syntactic and morphosyntactic agreement information is challenging in L2 processing, even for advanced L2 learners. I turn to these aspects now.

2.2. Syntactic Constraints in the L2 Processing of Nonlocal Dependencies

Research on nonlocal dependencies centers on the use of syntactic constraints in filler-gap dependencies (e.g., *wh*-questions, relative clauses) and in anaphoric dependencies (e.g., reflexives, pronouns), in L2 processing. I discuss each in turn.

2.2.1. Filler-gap dependencies and shallow structures. When interpreting filler-gap dependencies like *wh*-questions, comprehenders need to relate fillers to their lexical subcategorizer for interpretation. In monolingual processing, the parser immediately initiates a search for a potential gap site for a filler, such as a *wh*-word, postulating a gap as soon as possible (Active Filler Strategy; Clifton & Frazier 1989). In consequence, processing slows down when the parser encounters a gap that is filled by an overt element (filled-gap effect; Stowe 1986). L2 learners also show filled-gap effects, suggesting that they similarly engage in "active" gap-filling and relate fillers to the earliest available lexical licensors, such as subcategorizing verbs or prepositions (Dallas & Kaan 2008, Jessen & Felser 2019, Williams et al. 2001). To test syntactic constraints on gap filling, several studies probed whether native and non-native speakers allow for *wh*-extraction from syntactic islands, which grammatically prohibit extraction (for review, see Chaves & Putnam 2021). Across studies using different methods (self-paced reading: Omaki & Schulz 2011; eye-tracking: Felser et al. 2012) or diagnostics (Aldwayan et al. 2010, Kim et al. 2015a), L2 learners consistently obey syntactic locality constraints on filler-gap dependency formation, even if they experience delays (Boxell & Felser 2017) or L1 differences in the timing of their application (Kim et al. 2015a). In principle, then, L2 learners apply syntactic locality constraints incrementally in processing the L2.

A related line of research investigates whether L2 learners posit structurally required gaps in processing. Marinis et al. (2005) tested whether advanced L2 learners with various L1s would show facilitation in filler integration in sentences like example 2a, where the clausal complement projects an intermediate gap preceding the complementizer *that*. They contrasted self-paced reading times at the final gap position in example 2a with matched sentences that do not have intermediate gaps (example 2b):

(2a) The nurse who the doctor argued [___ that the rude patient had angered ___] is refusing to work late. (extraction across CP)

(2b) The nurse who the doctor's [argument about the rude patient had angered __] is refusing to work late. (extraction across NP)

For L1 readers, filler integration at the final gap was facilitated when they could previously reactivate it at the intermediate gap site in example 2a. In contrast, none of the L2 groups demonstrated reading differences between examples 2a and b. This finding suggests that learners do not posit hierarchical syntactic structure during sentence processing (see also Felser & Roberts 2007).

Such L1–L2 differences in the processing of filler-gap dependencies point to differences between L1 and L2 users in how much they recruit syntactic information in real time. As a consequence, the Shallow Structure Hypothesis (Clahsen & Felser 2006, 2018) holds that adult L2 learners rely less than native speakers do on syntactic parses and predominantly build sentence representations on lexical-thematic, semantic, and discourse information and/or surface heuristics, such as high-frequency word orders. Initially, the hypothesis tied the underreliance on grammatical parses to age constraints on acquiring abstract syntactic representations (Clahsen & Felser 2006). However, highly proficient learners with long L2 immersion experience display native-like processing of intermediate gaps (Pliatsikas & Marinis 2013), and even nonimmersed L2 learners have been found to posit gaps in studies that used more sensitive eye-tracking measures like pupillometry (Fernandez et al. 2018). Such instances of native-like L2 processing of abstract syntax underscore that shallow processing among L2 learners is not absolute but only a matter of degree, and may reflect the delayed application or a reduced weighting of grammatical versus nongrammatical information in L2 sentence processing (Clahsen & Felser 2018).

2.2.2. Referential processing and cue interference. Referential dependencies involving the interpretation of reflexives and pronouns provide insights into the different types of constraints L2 learners use in sentence comprehension, specifically, whether they prioritize discourse-based relations or adhere to syntactic constraints on coreference, such as the principles of Binding Theory (Chomsky 1981). Although the degree to which monolingual adults immediately apply binding constraints in referential processing is contested (for review, see Dillon 2014), several studies have reported that syntactic constraints on coreference restrict coreference in the initial processing of anaphoric dependencies (Sturt 2003). For L2 learners, Felser & Cunnings (2012) explored this issue by manipulating coreference options between a syntactic binder and a discourse-prominent coreferent in terms of stereotypical gender as in example 3. In example 3, the reflexive pronoun either only had one likely antecedent (*soldier*) or had two possible antecedents (*James/He*, *soldier*), with the syntactically accessible binder (*soldier*) being either the local (example 3a) or the nonlocal (example 3b) antecedent:

(3a) James/Helen has worked at the army hospital for years. He/She noticed that the soldier had wounded himself/herself while on duty in the Far East.

(3b) James/Helen has worked at the army hospital for years. The soldier that he/she treated on the ward wounded himself/herself while on duty in the Far East.

For both sentence types, L1 German learners of English showed slowdowns in early eye-tracking measures if the syntactically inaccessible discourse-prominent coreferent (*he* versus *she*) mismatched in gender with the reflexive, while native English readers were sensitive to gender mismatches between the binder with the reflexive (*himself* versus *herself*). The L2 speakers only became sensitive to the local binding mismatch in later rereading times on the reflexive, which led Felser & Cunnings (2012) to conclude that L2 learners initially construe coreference with discourse-prominent antecedents. Research on restrictions on the local binding of personal pronouns is compatible with this assumption, as L2 readers initially only consider salient nonlocal antecedents, even when a local binder for the pronoun is available (Kim et al. 2015b, Patterson et al. 2014).

At first glance, such partially non-native-like L2 processing of referential dependencies seems difficult to reconcile with the sensitivity L2 learners show for syntactic restrictions on the formation of filler-gap dependencies (Section 2.2.1). Yet, Felser (2015) noted that filler-gap dependencies differ from anaphoric dependencies in that filler-gap relations constitute forward-looking dependencies, while the processing of anaphors involves backward-looking dependencies. Building on this distinction, Cunnings (2017) proposed to account for L1–L2 differences in the context of retrieval-based models of comprehension (e.g., Lewis et al. 2006). Establishing intrasentential anaphoric dependencies requires access to memory representations of potential antecedents and of partial sentence representations built previously. In cue-based parsing, all representations encoded in memory compete for selection, and the item that best matches the cues needed is selected. Critically, cue-based retrieval is subject to similarity-based interference. For L2 processing, Cunnings (2017) stipulated that retrieval from memory is subject to greater cue interference, especially from discourse cues. Beyond accounting for greater L2 susceptibility to discourse antecedents in referential processing, Cunnings's (2017) approach captures stronger semantic persistence effects among L2 learners in the reanalysis of garden-path sentences (Section 2.1). Under a cue-based account, semantic persistence effects reflect interference from the initial misparse that lingers in memory and is erroneously retrieved. However, to date there is little direct evidence that L2 learners suffer greater cue interference than do natives, for instance, in the processing of agreement (Tanner et al. 2012).

In sum, research on syntactic constraints in L2 sentence processing suggests that L2 users struggle in constructing nonlocal grammatical dependencies in real time and initially tend to map a sentence to interpretation using nongrammatical cues, such as lexical-semantic or discourse information. Recent work indicates that the relative underreliance on grammar is a matter of timing and degree rather than a qualitative difference that sets L2 processing apart from L1 sentence comprehension. In this sense, current theorizing within difference-oriented approaches points to some convergence with identity-oriented approaches by relating difficulties with grammatical information to the less robust encoding and delayed retrieval of morphosyntactic information in real time.

2.3. Agreement and Lower Degrees of Predictive Processing

A more recent line of research shifts attention from investigating the types of information that are particularly challenging for L2 users to the processes that may be subject to L1–L2 differences. On top of integrating information into an ongoing parse, monolinguals use bottom-up and top-down information to predict how an incoming sentence will continue to unfold. The clearest evidence for predictive processing comes from event-related potential (ERP) studies and eye-tracking studies employing the visual-world paradigm (Huettig et al. 2011), which can measure predictive processing before readers or listeners encounter the predicted element (for review, see Pickering & Gambi 2018). In these studies, linguistic information restricts the set of eligible referents that can follow. For instance, in a sentence like *The boy will eat*. . . , the combination of an agentive subject and the verb semantics restricts the possible complement of the verb to edible objects (Altmann & Kamide 1999). In other languages, grammatical information on articles can restrict the set of upcoming referents to members of a grammatical gender class [e.g., Spanish: *Encuentra la*. . . (Find the$_{\mathrm{FEM}}$ $\rightarrow$ N$_{\mathrm{FEM}}$)] or, for case, specify the syntactic function of upcoming nouns [e.g., German: *Den Jungen sieht*. . . (The$_{\mathrm{ACC}}$ boy sees $\rightarrow$ N$_{\mathrm{NOM}}$)]. L2 learners appear to differ from L1 speakers in the degree to which they actively predict upcoming information (Kaan 2014). Moreover, predictive processing differs according to the linguistic domain among L2 learners.

On the one hand, even intermediate-level L2 learners robustly use lexical semantic information for prediction, for instance, by restricting their looks to edible objects after they have encountered the verb *eat* in visual-world studies (e.g., Chambers & Cooke 2009, Dijkgraaf et al. 2017, Hopp 2015b, Ito et al. 2018). When there are differences between monolinguals and L2 learners in semantic prediction, they predominantly reflect experiential variation between groups in the type and amount of input. For instance, L1 effects emerge for fine-grained semantic predictions, such as in the domain of caused motion involving placement events (van Bergen & Flecken 2017). Unlike English with its cover-all verb *put*, Dutch and German use different verbs for placing objects into upright (*zetten/stellen*) or horizontal (*leggen/legen*) positions. When encountering placement verbs, native speakers of Dutch immediately orient their gazes to objects that match the verb's spatial semantics. Among L2 speakers, only L1 German learners of Dutch, but not L1 French or L1 English learners, demonstrated predictive use of the verb's specific selectional requirements. This finding suggests that L2 learners rely on L1-based distinctions. In addition, semantic and associative predictions tend to be more local among L2 learners than among monolingual adults. For instance, when listening to a sentence like *The pirate chases the ship*, L2 learners briefly look at the display of a locally coherent referent (*chase* → cat) even though this referent does not match the global expectation (Peters et al. 2018). Yet, more highly proficient L2 learners who have more L2 experience make fewer locally coherent predictions, and even monolingual children and adults show similar patterns of local or attenuated prediction, especially when they process the sentences under increased cognitive load (Ito et al. 2018).

On the other hand, even advanced L2 learners continue to have difficulties in using syntactic structure (Kaan et al. 2016) and agreement information for prediction, such as grammatical gender marking (Grüter et al. 2012, Lew-Williams & Fernald 2010) and case marking (Hopp 2015b, Mitsugi & MacWhinney 2016). For instance, near-native L1 English learners of Spanish do not employ gender marking on articles to predict upcoming familiar nouns even though they are highly accurate in production and in offline tasks on gender agreement (Grüter et al. 2012). As with semantic prediction, successful morphosyntactic prediction in the L2 partially depends on the L1 in that adult L2 learners are more target-like when their L1s have similar gender systems (e.g., Morales et al. 2016) or employ case distinctions (Frenck-Mestre et al. 2019). However, unlike for semantic predictions, having an analogous morphosyntactic feature in the L1 does not always entail native-like processing of gender in the L2 (Dussias et al. 2013).

Some accounts, such as the RAGE Hypothesis (Grüter et al. 2017), argue that predictive processing is attenuated in an L2 (see also Kaan 2014). Reduced predictive processing is by no means limited to L2 users, though, as the degree of predictive processing differs between individuals or situations. For instance, elderly monolinguals engage less in predictive processing than middle-aged adults do (Federmeier 2007), as do adults with low literacy skills (Mishra et al. 2012) or dyslexia (Huettig & Brouwer 2015). In addition, L1 adults adapt their predictions according to the usefulness of cues available for prediction in a particular context (Henry et al. 2017). In this vein, Kuperberg & Jaeger (2016) construe prediction in terms of its utility function, claiming that comprehenders maximize the utility of predictive processing by preactivating information at those levels of representation only to the extent that it serves their goal of facilitating comprehension. While the utility of prediction may be different relative to the task and situation of the comprehender, the utility of prediction in an L2 context can also vary depending on the linguistic knowledge of the learner.

For instance, predictive processing in the L2 may be weighted differently in utility when various cues compete. Grüter et al. (2020) examined competition between grammatical class membership and semantic prototypicality in the predictive use of Mandarin classifiers. Unlike native Mandarin speakers, advanced L2 learners showed anticipatory looks to semantically matching nonclass competitors, which suggests that the learners prioritize semantic over grammatical cues (see also Hopp 2015b). Critically, differences between L1 and L2 processing manifested not in less or slower prediction among the L2 learners but rather in qualitatively different predictions in that L2 learners assigned the high reliability of semantic cues a greater utility than less transparent grammatical cues. In a similar vein, Hopp (2013, 2016) found that the degree of predictive processing of gender agreement was related to variability in the lexical knowledge of grammatical gender. Even after L2 learners have acquired the gender of most nouns, their lexicon contains nouns with unknown, variable, or incorrect gender. Since many predictions based on variable or incorrect lexical gender representations would lead to prediction error and require revision, using gender for prediction may be too costly. In Hopp (2013, 2016), L2 learners with less than perfect lexical knowledge of gender did not use gender predictively even though they produced the gender agreement correctly. Only learners with consistent gender knowledge demonstrated predictive gender processing. Critically, native speakers also suspended prediction by gender once gender became an unreliable cue in the course of an experiment that was designed to emulate the variability typical of the L2 lexicon by including nouns with nontarget gender marking in the input to participants (Hopp 2016).

What these findings suggest is that predictive processing in both L2 and L1 processing varies as a function of its utility compared to the costs of making unreliable or erroneous predictions (see also Grüter & Rohde 2021). When predictions keep going amiss, the parser may wait and integrate the input rather than engage in making a prediction. In consequence, L1–L2 differences in the degree of prediction may follow from differences in the likelihood of making false predictions. As research on prediction in L2s accumulates, it appears that L1–L2 differences in predictive agreement processing may not necessarily index a reduced availability of predictive mechanisms, their limited scope, or their slower deployment. Instead, they may point to differences in the utility function of prediction relative to the linguistic knowledge of L2 learners.

2.4. L1–L2 Differences in Sentence Processing: Conclusions and Challenges

In all fundamental respects, processing a sentence in an L2 is identical to monolingual sentence processing. Late L2 learners process L2 sentences incrementally, and they integrate and predict linguistic and nonlinguistic information. Across the three areas surveyed above, both the integration and prediction of nongrammatical information are robust in L2 learners; yet, L2 learners tend to make attenuated use of grammatical information and prediction compared to monolinguals. From this review, it becomes clear that the reasons for these specific L1–L2 differences are unlikely to be monolithic. Instead, the major lines of research reviewed above suggest multiple causes, including (*a*) computational restrictions in the ability to integrate information or to effect full parses including reanalysis in an L2; (*b*) L1–L2 differences in the weighting of information or cues, the timing of their application, or the efficiency of their retrieval; and (*c*) variation in the utility functions of particular processing mechanisms in L2 versus L1 processing. Currently, research in L2 sentence processing aims to disentangle the relative contributions of these causes and, in particular, the extent to which they interact with individual differences in working memory (Linck et al. 2014), executive function (e.g., Teubner-Rhodes et al. 2016), and L2 experience and proficiency (Sagarra 2022). As the field increasingly adopts methods with higher temporal resolution, like eye-tracking and electroencephalography, studies can pose more nuanced questions about individual differences as well as between-group L1–L2 differences in terms of the timing and weighting of different constraints (Felser 2019).

At the same time, such shifts to timing and weighting issues foreground differences across studies in how findings are interpreted when L2 learners are delayed or less robust in their sensitivity to some constraint compared to monolinguals. On the one hand, when L2 learners demonstrate some sensitivity to a constraint during real-time processing at all, one may conclude that L2 sentence processing is qualitatively identical to native processing, and that delays or minor differences in performance are essentially noise, owing to factors exogenous to the parser (e.g., individual and between-group differences in cognitive capacity, lower-level processing skills, inexperience with the target language). On the other hand, timing differences may be taken as a signal that indexes qualitative differences in the parser, its knowledge bases, or its mechanisms (for discussion, see Clahsen & Felser 2018, Roberts 2013). Now that the field is moving from posing questions in terms of whether L2 users can process *X* like native speakers to how they process *X*, it is high time to start a discussion about how to distinguish signal from noise in data interpretation, especially since, by definition, L2 performance is more variable than monolingual performance because of larger differences in language experience across bilingual populations.

Beyond raising these methodological issues in data interpretation, variation in bilingual performance also points to a systematic limitation of the current research paradigm that remains wedded to the comparison of L2 processing to monolingual parsing. In using the yardstick of monolingual performance as the sole reference point in the study of L2 processing, much research has turned a blind eye to features of sentence processing that are unique to bilingualism. In the following section, I outline why these features should move center stage.

3. NEW DIRECTIONS: TOWARD INTERLANGUAGE PROCESSING

Unlike adult monolinguals, whose processing is subserved by one stable linguistic system, the knowledge and processing of L2 learners are characterized by the copresence of L1 and L2 properties, ongoing L2 development, and sometimes fossilization in that a learner's L2 stops developing short of the target language. In a seminal paper, Selinker (1972) captured these features of L2 acquisition in the notion of interlanguage, which he described as a system comprising L1 and target-language features, as well as learner-specific generalizations, with learners proceeding from one interlanguage stage to the next in the course of L2 development. Formal studies of L2 acquisition have attempted to provide a grammatical analysis of interlanguage grammars at different stages of development (e.g., Lardiere 2009, Schwartz & Sprouse 1994). By contrast, L2 processing studies usually abstract away from features of the interlanguage system and make a direct comparison to monolingual performance. Such a perspective misses out on examining whether L2 processing is grammatically constrained by the interlanguage system, even in cases when the latter differs from monolingual grammars by virtue of representing more than one linguistic system or when it exhibits nontarget features stemming from the L1. Finally, this perspective cannot account for interlanguage development, that is, how learners move from one stage to the next in interlanguage development. In the following sections, I discuss these three core features of interlanguage processing, namely, (*a*) the role of bilingual grammars in processing, (*b*) L1 effects and parser–grammar relations, and (*c*) relations between (interlanguage) processing and development. I build on the scarce empirical evidence we have so far on these topics in order to sketch new directions for research on L2 sentence processing that cross-cut and transcend the traditional framing of research on L2 sentence processing within difference-based and identity-based approaches relative to L1 processing.

3.1. Bilingual Systems and L2 Sentence Processing

Interlanguage systems comprise features of all the languages a bilingual knows as well as idiosyncratic properties. During sentence comprehension and production, bilinguals accordingly activate (sub)lexical representations and grammatical features across all of their languages (for review, see Tokowicz 2015). For instance, bilinguals show different processing of language-ambiguous word forms, such as cognates (e.g., *film*$_{\text{GERMAN/ENGLISH}}$) and homographs (*gift*$_{\text{GERMAN/ENGLISH}}$), compared to language-particular word forms (e.g., *tree*$_{\text{ENGLISH}}$–*Baum*$_{\text{GERMAN}}$), even when reading these words in sentence contexts (for review, see van Assche et al. 2012). Crucially, non-language-selective access in the bilingual lexicon has nontrivial consequences in sentence comprehension.

For one thing, the non-language-selective activation of lexical representations affects the time course and staging of L2 sentence processing. Slower lexical access among L2 learners can delay the application of syntactic structure building (Cheng et al. 2021, Hopp 2016), while lexical coactivation of the L1 in the bilingual mental lexicon, by virtue of cognates, speeds up lexical access and thus facilitates L2 structure building (Hopp 2017, Miller 2014) and L2 agreement processing (Morales et al. 2016). For another, the integrated nature of lexical representations in bilinguals engenders qualitatively different profiles in L2 sentence processing. For instance, adult high-intermediate L1 Russian learners of L2 German use gender agreement on German articles predictively only for nouns whose Russian translation equivalents have the same grammatical gender, while they do not use gender for incongruent nouns despite knowing and producing the target L2 gender for them (Hopp & Lemmerth 2018). L2 learners thus compute syntactic agreement according to both L1 and L2 grammatical features simultaneously (see also Meir et al. 2020). Similarly, habitual Spanish–English code-switchers extend grammatical asymmetries in code-switched noun phrases to gender agreement processing in monolingual Spanish sentences (Valdés Kroff et al. 2017), leading to performance differences compared to monolingual speakers of Spanish.

Such findings illustrate that bilinguals may be non-native-like in their processing performance, while their processing is in perfect alignment with their interlanguage systems. In this way, effects of bilingualism can lead to non-native sentence processing in an L2 because the parser operates on representations in interlanguage systems that are by definition distinct from monolingual systems. Bilingualism effects of this type are not restricted to the lexicon and can be observed at all levels of representation. For instance, L1 constraints on prosodic structure can interfere with the processing of L2 inflection, giving rise to divergent sentence processing (Goad & White 2019). Instead of investigating whether L2 performance during processing can be native-like, then, a more pertinent question that directly addresses the architecture of the language processing system in bilinguals is to examine whether the L2 parser executes parses in accordance with the non-native-like interlanguage system, as assessed independently, for instance, in offline tasks.

Such an orientation also widens the scope of research on L2 sentence processing. Recognizing that the linguistic knowledge of bilinguals is different from that of monolinguals, research on L2 sentence processing is slowly beginning to follow the "bilingual turn" in studies on L2 acquisition (Ortega 2010) and increasingly compares sentence processing across different types of bilinguals. Such comparisons allow researchers to hold the factor of bilingualism constant to explore differences within bilingual sentence processing in terms of variation in input quantity and quality, age, and sequence of acquisition.[1]

For instance, Lemmerth & Hopp (2019) adapted the study on predictive gender processing by adult L2 learners of German discussed above (Hopp & Lemmerth 2018) to simultaneous bilingual Russian-German and early successive bilingual Russian-German children aged 8 years. While simultaneous bilingual children patterned with monolingual age-matched German children in using gender for prediction throughout, early successive bilinguals, who had only been exposed to Russian up to age 2½ years, could use German gender predictively only when noun gender was congruent with the Russian translation equivalent. Unlike the adult learners of German in the study by Hopp & Lemmerth (2018)—who also had more difficulty with gender on articles, which do not exist in Russian—the child L2 learners were not affected in their use of gender by differences between the L1 and L2 syntax. Such asymmetric performance of successive child L2

[1]Of course, bilingual comparisons do not obviate the need for an L1 control group in a study to show that the experimental manipulation works. However, L1 speakers should not invariably constitute the reference group for bilingual performance.

and adult L2 learners suggests that effects of bilingualism in the lexicon and in the grammar bear different signatures depending on the age of onset.

Next to studies comparing child and adult L2 sentence processing, processing research is gathering pace on adult L1 attriters (i.e., long-term emigrants with little continued L1 input whose L2 has become their dominant language in adulthood; Schmid 2011) and L1 heritage speakers (Montrul 2016). These studies investigate the directionality of bilingualism effects by contrasting forward (L1 to L2) and reverse (L2 to L1) cross-linguistic influence. Emerging research on sentence processing in L1 attriters points to some L2 influence in L1 parsing preferences (Dussias & Sagarra 2007), but L1 attriters continue to show monolingual-like performance with the L1 grammar in sentence processing (Bergmann et al. 2015, Grüter & Hopp 2021; though see Kasparian & Steinhauer 2017). These initial findings from L1 attrition tie in with research on sentence processing in L1 heritage speakers who experienced a dominance shift from the L1 to L2 in childhood, yet do not resemble late L2 learners in parsing, and largely pattern with monolingual children and adults (Polinsky 2018; though see Jegerski & Sekerina 2020). Such emerging research suggests a crucial role for age of acquisition within bilingual sentence processing. To assess whether different processing profiles between bilingual groups indicate that late L2 learners employ processing strategies that deviate from their interlanguage representations, we need careful investigations of both the linguistic knowledge and the language processing across different types of bilingual populations.

In sum, going beyond the monolingual reference point in the study of L2 sentence processing allows researchers to investigate the degree to which L2 sentence processing conforms to bilinguals' linguistic knowledge, which is necessarily different from monolingual linguistic knowledge. This shift in perspective implicates the comparative study of sentence processing in different bilingual groups to assess how variation in age of onset, sequence of acquisition, and input may affect bilingual sentence processing. Not least, such a bilingual perspective on L2 sentence processing can reframe the view of L2 sentence processing away from being a deficient counterpart to monolingual sentence processing. Instead, interlanguage processing affords an opportunity to investigate and comprehend how language processing operates relative to the knowledge of bilingual speakers.

3.2. The L1 Transfer Paradox and Parser–Grammar Relations

By definition, the L1 is part of the linguistic knowledge of L2 learners, and transfer or cross-linguistic influence from the L1 surfaces in L2 sentence production and comprehension. Even L2 learners at more advanced stages of L2 acquisition show optionality between the use of L1-based and L2-based grammatical options in production and often accept both L1 and L2 options in comprehension (for review, see Foley & Flynn 2013).

As reviewed in previous sections, L2 learners also show some L1 differences in integration and prediction in the processing of lexical and inflectional information, for which L1–L2 overlaps facilitate L2 processing (e.g., Dussias & Cramer Scaltz 2008, Frenck-Mestre & Pynte 1997, Frenck-Mestre et al. 2019, van Bergen & Flecken 2017). For syntactic processing, though, the evidence that L2 learners refer to the L1 grammar or L1 parsing strategies is rather limited. For instance, L2 learners garden-path during L2 processing irrespective of L1 word order differences (Juffs 2004), and their L1 parsing preferences do not consistently affect structure-based relative clause attachment preferences in the L2 (e.g., Felser et al. 2003). To investigate the status of the L1 grammar in L2 processing, several studies examined "cross-language syntactic conflicts" (Kaan et al. 2015), in which the surface word order in the L2 can be mapped to a different interpretation using the L1 grammar. Building on the work of Jacob (2009), Hopp (2017) studied whether L1

German learners coactivate the L1 grammar and assign an L1-based parse to L2 input. In example 4, the verbatim translation of the preposed adjunct clause (underlined in the example) maps to a canonical embedded clause in German because of its SOV word order, while it represents an infrequent reduced relative clause in English:

(4) <u>When the doctor Sarah ignored</u> tried to leave the room the nurse came in all of a sudden.

Compared to control sentences, reading time differences for example 4 indicative of L1 activation were observed only in experiments in which English target sentences were interspersed with German filler items. By contrast, when reading in English-only contexts, no reading time differences indicative of L1 effects surfaced. Yet, even in language-mixing contexts, L1 effects can be elusive. For instance, in a visual world eye-tracking study using structural priming, object question primes in their L1 German did not induce German learners of English to process English subject *wh*-questions using their L1 grammar, even though the L1 grammar allows for an object *wh*-question parse of this string (Hopp & Grüter 2021).

Under the widely held assumption in L1 and L2 processing research that the parser directly recruits grammatical information (for review, see Juffs & Rodriguez 2014), both the L1 grammar and the L2 interlanguage grammar should affect parsing in L2 users; yet, the L1 grammar seems to be conspicuously absent in L2 processing. At the same time, L1 effects often surface in sentence-final interpretations. For instance, Kaan et al. (2015) examined whether L1 Dutch advanced English learners would parse ungrammatical relative clauses such as *Mark may know the instructor who the students *has avoided* as subject relative clauses as per Dutch OV syntax. In self-paced reading, the L2 group did not show any reading time differences between locally mismatched singular or plural nouns inside relative clauses that would reflect use of Dutch word order online, yet they did give more subject interpretations of the mismatched condition that was compatible with Dutch syntax in end-of-sentence decisions. In other words, even though advanced L2 learners do not appear to activate the L1 grammar during real-time processing, they make recourse to L1 grammars in subsequent judgment or decision tasks (see also Hopp & Grüter 2021, Rankin et al. 2019, Roberts et al. 2008).

These L1 effects indicate that L2 learners partially compute grammatical L1 parses alongside L2 parses. However, L1 parses appear to have a low resting level of activation compared to the L2 grammar, especially among advanced L2 learners. Once this activation is upped by language mixing (Hopp 2017, Jacob 2009), L1 effects become visible during processing. Similarly, L1 activation can be enhanced by sentence-final judgment or decision tasks (Kaan et al. 2015). Here, participants are presented with two possible interpretations: One corresponds to the L2, and the other is licensed by the L1 grammar. When participants need to assess and compare both interpretations, L2 learners can apply an L1-based parse to the nontarget interpretation and thus sometimes recover an additional or different interpretation of the sentence when the parseable L1 option wins out over the L2 option (Hopp & Grüter 2021).

Under this view, L2 parsing relates to grammatical approaches to L2 acquisition which argue that interlanguage grammars simultaneously encode L1 and L2 representations, with previous L1-based or developmental grammatical representations lingering and competing for selection throughout the course of L2 development (Amaral & Roeper 2014, Westergaard 2021). According to these approaches, L1 grammatical options constitute inherent and persistent features of interlanguage grammars and can be activated alongside L2 options. Interlanguage processing can probe the conditions and limits of how the parser recruits the L1 grammar vis à vis the L2 grammar to uncover the dynamics of grammatical cross-linguistic influence. Specifically, research can weight the activation of the L1 grammatical options and study when and how L2 learners recruit

L1 grammatical properties in L2 parsing at different developmental stages, at different processing steps, and under different task demands.

By investigating the degree to which sentence processing is non-language-selective, an interlanguage perspective on L2 sentence processing also enters into dialog with current approaches to the bilingual lexicon (e.g., Dijkstra et al. 2019) and bilingual speech processing (Grosjean & Byers-Heinlein 2018). As it strives to compare bilingual lexical and sentence processing (rather than monolingual and L2 processing), it holds the promise of integrating sentence processing within a unified architecture of the bilingual language processing system.

3.3. Processing to Learn and the Pitfalls of Less Prediction

To acquire a language, a learner needs to be able to process it, so that novel information can be acquired (e.g., Fodor 1999, Omaki & Lidz 2015). The relevance of processing as a prerequisite for learning has recently gained traction in the context of predictive processing (Section 2.3). A parser that makes predictions about the unfolding input can learn whenever it experiences a prediction error, that is, when the parser's predictions are disconfirmed by the input. By way of predictive processing, a learner can thus actively test grammatical hypotheses about the target language against the input since a prediction error creates feedback for the parser (e.g., Phillips & Ehrenhofer 2015). After having encountered a prediction error, the parser can adjust processing or its linguistic knowledge base to match the input and decrease future prediction error (Dell & Chang 2014, Kleinschmidt & Jaeger 2015).

In adult sentence processing, structural priming and syntactic adaptation have been used as methods to study learning via prediction error (for review, see Kaan & Chun 2018). When exposed to a high number of sentences containing complex structures, such as reduced relative clauses, monolingual adults cumulatively adapt their sentence processing in that the processing costs of the complex structures are reduced (Fine et al. 2013, Yan & Jaeger 2020). These effects of syntactic adaptation suggest that users continuously update their parsing preferences as a result of incoming input. The evidence on whether L2 learners also adapt their sentence processing is mixed. On the one hand, studies on structural priming among L2 learners show that adult L2 learners demonstrate priming effects in similar magnitude to monolinguals (for review, see Jackson 2018). In structural priming, speakers reuse a structure they have just heard, or readers have less processing difficulty with a complex syntactic structure if the preceding sentence was of a similar type. These trial-by-trial effects indicate that L2 learners adjust their processing in similar ways as monolinguals do. In prediction-based accounts (e.g., Dell & Chang 2014), priming constitutes implicit learning in that the language user decreases the misalignment between predicted and observed structures in the input. On the other hand, sentence processing studies on L2 syntactic ambiguities report that adult L2 learners continue to show processing difficulty with dispreferred or complex structures even after prolonged exposure to these structures in the input (Kaan et al. 2019), indicating that they do not use adaptive mechanisms or that they may need more input than do native speakers to adapt.

Beyond testing whether L2 learners adapt their syntactic processing preferences in ambiguous sentences, some studies explore whether massed input inducing prediction error can counteract the underuse of grammatical information in L2 sentence processing and lead to the integration of morphosyntax and successful reanalysis. In a reading study with an experimental group and a control group, Hopp (2020) investigated whether massed input designed to systematically induce prediction error would lead to the use of case marking for reanalysis among intermediate to advanced L1 German learners of English. In potential garden-path sentences like *When the spectators were applauding they remained in the spotlight*, L2 learners routinely construe the postverbal pronoun as the object of the verb (see also Hopp 2015a). Such garden paths indicate that readers have a strong prediction for a (potentially) transitive verb to be followed by an object. Following a pretest using eye-tracking during reading, the experimental group in the study by Hopp (2020) read sentences for comprehension that contained consistent intransitive uses of optionally transitive verbs (e.g., *The boy played and he pleased the parents with the music*). In these sentences, the verb was followed by a coordinating conjunction (*and*) and an unambiguously nominative case-marked pronoun (*he*), which together highlighted the beginning of a new clause. These sentences were intended to create frequent prediction errors, since the verb was not followed by an object and the pronoun was clearly a subject. The control group read matched input with transitive readings of the verbs (*The boy played the music and it pleased the parents*) that would not lead to any prediction error. In posttests, the reading patterns for garden-path sentences among the control group were unchanged from the pretest, while the experimental group did not demonstrate garden paths anymore, indicating that the readers had adapted to analyzing the postverbal pronoun as a subject, arguably as a result of experiencing frequent prediction errors in the massed input. These initial findings suggest that adaptation and implicit learning via prediction error can lead L2 learners to use case marking as a reanalysis cue during L2 sentence processing. However, more research is needed to delineate the scope of adaptation among L2 learners and to identify the nature of the mechanisms involved in syntactic adaptation. Furthermore, open questions remain as to whether syntactic adaptation during online processing translates into longer-term learning as measured in different or delayed tasks (see Jackson & Hopp 2020).

Critically, typical features of L2 sentence processing could affect the success of learning (for discussion, see Hopp 2021). First, lower degrees of predictive processing in the L2 may create obstacles to learning in that learners cannot generate sufficient feedback by virtue of prediction error during sentence processing (Phillips & Ehrenhofer 2015). Second, L2 learners often base their predictions on nongrammatical information (Section 2.3). However, learning from prediction error can only be successful if learners can track the nature of their prediction error and then update their predictions accordingly. If learners predominantly generate predictions on the basis of semantic information, prediction errors will not be informative for learning the L2 grammar. In these regards, characteristic features of L2 sentence processing may impose limits on learning the L2.

4. CONCLUSION

Two decades of systematic research on L2 sentence processing have led to a better understanding of how L2 learners differ in their real-time sentence comprehension from L1 speakers. There is now widespread agreement that, rather than being monocausal, L2–L1 differences reflect the interplay between differences in the integration and prediction of different cues, their utility, and cognitive constraints on processing in real time. As much as the field is making strides toward more nuanced views of L2 sentence processing, it upholds native-speaker benchmarks of performance, which, in turn, perpetuate L2 sentence processing as a deviant or deficient form of monolingual parsing and limit the scope of inquiry. Interlanguage processing breaks with the monolingual standard and widens the lens to capture characteristic features of L2 acquisition, such as bilingual knowledge systems, L1 transfer, and L2 learning and its limits. Such a shift in perspective comes with opportunities for novel insights, yet also with novel challenges. In particular for lower-proficiency L2 learners, who do not yet have a stable command of the L2, careful experimentation is necessary to link the processing of a particular linguistic property to its ongoing acquisition. In these respects, it will be fruitful to align research on natural L2s with studies on artificial or miniature languages (see sidebar titled Sentence Processing in Artificial

SENTENCE PROCESSING IN ARTIFICIAL AND MINIATURE LANGUAGES

As a corollary to research on the L2 processing of natural languages, studies on artificial language (AL) explore sentence processing in laboratory-constructed nonce languages or miniature versions of natural languages. As "test tube" models of natural language processing, they have full control over the type and amount of input, including similarities between the AL and learners' previous languages (for review, see Grey 2020, Morgan-Short 2020). Typically using ERPs, they examine the limits of AL/L2 processing and patterns of development. Learners who have achieved high proficiency in the AL after massed exposure in a short time demonstrate a range of early ERP signatures in response to lexical-semantic and morphosyntactic violations comparable to those observed in monolingual natural language processing. In the course of learning, AL learners often proceed through a series of processing stages, moving from prioritizing lexical semantics or L1-based strategies to integrating morphosyntax (see also Osterhout et al. 2006 for natural L2s). Finally, AL studies manipulate the type of input between more naturalistic, implicit training and exposure to explicit rules. Both explicit and implicit learning lead to successful AL processing. Yet, only learners who become aware of rules during implicit training engage the full set of processing mechanisms in an AL, including prediction (Andringa 2020).

Despite continuing concerns about their ecological validity, AL studies cohere with findings from natural L2 learning that L2 sentence processing is fully constrained by the architecture and processes that subserve monolingual processing (Section 2). By way of longitudinal study of (fast-tracked) development, they offer complementary insights into the dynamics of cross-linguistic influence (Section 3.2) and the implicit and explicit processing mechanisms used in learning (Section 3.3).

and Miniature Languages). Moreover, the growing number of multilinguals, who speak more than two languages, adds complexity to the study of non-native processing (González Alonso & Rothman 2022). These challenges equally highlight the potentials and contributions that the investigation of bilinguals and multilinguals can make to our understanding of sentence processing and, conversely, how the study of L2 sentence processing can establish itself as a central area in research on L2 acquisition and bilingualism.

DISCLOSURE STATEMENT

The author is not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

ACKNOWLEDGMENTS

I would like to thank Theres Grüter, Carrie N. Jackson, Duygu Şafak, and the journal's Co-Editor Colin Phillips for critical comments that helped improve the quality of the manuscript.

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