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# Asymmetrical effects of cross-linguistic structural priming on cross-linguistic influence in L2 learners

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## Abstract

The present study investigates current proposals that priming is a mechanism of cross-linguistic influence (CLI) in bilinguals by aiming to boost CLI through priming. In two cross-linguistic structural priming experiments with less-proficient adolescent (Study 1) and more highly proficient adult German-English learners (Study 2), we assess whether structural priming enhances CLI for well-formed, dispreferred, and ungrammatical structures. L2 learners in both studies showed CLI in their production, in particular for structures with word order overlap. They also exhibited short-term cross-linguistic priming of grammatical L1-L2 word orders in L2 English, which extended to longer-term priming among the more highly proficient learners in Study 2. However, there was no evidence that cross-linguistic priming increased the use of dispreferred or ungrammatical L1-based word orders in L2 English in either study. Rather, the overall production of these word orders decreased. Together, these results suggest that, while cross-linguistic priming leads learners to increase the use of shared, grammatical L1-L2 word orders, it leads to the inhibition of non-shared ungrammatical structures in L2 production. We conclude that priming has asymmetrical effects on CLI of grammatical and ungrammatical L1-based structures in the L2.

**Keywords:** cross-linguistic influence; cross-linguistic structural priming; inhibition; learning

## Introduction

Cross-linguistic influence (CLI) is a hallmark of second language (L2) acquisition and bilingualism. L2 learners and bilingual speakers sometimes use properties of their other language(s) in the comprehension and production of one language. At the grammatical level, a "syntactic accent" (MacWhinney) characterizes both early bilinguals (van Dijk et al., 2022) and late L2 learners (Yu & Odlin, 2016) to different degrees. In beginning learners, such effects have been modeled as the representational transfer of the L1 grammar into the interlanguage of learners (e.g., Schwartz & Sprouse, 1996) or as learned

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attention of L2 learners to L1 cues and constructions (e.g., Ellis & Wulff, 2020). Yet, even when learners progress in their interlanguage development, they continue to use L1 word order options some of the time. Such instances of CLI in language use have been argued to reflect "grammar competition" or the co-activation of the other-language grammar in that grammatical structures from both or all languages of speakers compete for activation (e.g., Amaral & Roeper, 2014; Sharwood-Smith & Truscott, 2014). While CLI is by now uncontested as a feature of bilingualism and many studies have studied the scope of cross-linguistic influence in production and comprehension, little is known about the psycholinguistic mechanisms underlying CLI.

Cross-linguistic structural priming has been used as a method to gauge the extent to which bilinguals share syntactic structures (Hartsuiker & Bernolet, 2017). Structural priming refers to the facilitated use of constructions after listeners have encountered these structures in the input (Bock, 1986). Many studies show that identical structures can also be primed across languages in bilinguals (for review, Van Gompel & Arai, 2018). In the recent literature on child bilinguals, several researchers have proposed that cross-linguistic priming is not only a *method* to study cross-linguistic influence but denotes a *mechanism* that underlies cross-linguistic influence in L2 production generally (e.g., Nicoladis, 2006; Serratrice, 2013, 2016, 2022; see also Bosch & Unsworth, 2021). According to these accounts, the alternating use of two languages activates shared nodes of both languages that compete for selection in production or comprehension. Such effects have been described as the consequence of the global increase in L1 activation when bilinguals switch between languages (Serratrice, 2016, 2022) or of the mutual activation of lexical candidates which then spreads to the grammatical constructions in which these words are embedded (e.g., Nicoladis, 2012).

In this paper, we explore the scope of cross-linguistic priming as a mechanism of CLI by examining whether cross-linguistic priming boosts CLI and whether priming exhibits typical features that characterize CLI. Critically, CLI refers not only to the sharing of well-formed grammatical structures across languages but typically to the use of structures that are dispreferred or downright ungrammatical in the target language. For instance, L2 learners sometimes use L1 word orders in the L2 that violate the L2 grammar (e.g., Rankin, 2009), or they carry over word order preferences from the L1 to L2 production, although these very orders are dispreferred in the L2 (Jackson et al., 2017; Runnqvist et al., 2013). Both in child bilinguals and in adult L2 learners, such "negative" CLI surfaces particularly strongly for phenomena where the grammatical structures partially overlap in word order (Hopp, 2017; Hulk & Müller, 2000). In two studies, this paper therefore tests whether – like CLI – cross-linguistic priming also scopes over grammatical and ungrammatical structures and whether it is modulated by partial word order overlap. The studies build on the rationale that cross-linguistic structural priming likely only constitutes a psycholinguistic mechanism of CLI if it is susceptible to the very features by which CLI is characterized more broadly in L2 acquisition.

As a general research question, we therefore investigate whether cross-linguistic priming systematically occasions CLI among sequential L2 learners, who commonly display more CLI than early bilinguals. In two studies with low-intermediate adolescent L2 learners (Study 1) and mid-to-high proficiency adult L2 learners (Study 2), we test the specific research questions whether cross-linguistic structural priming

equally augments (a) CLI of well-formed optional word orders that are shared between German and English, namely the fronting of temporal adverbials, and (b) CLI of non-shared structures, that is, dispreferred word orders in terms of the relative ordering of adverbials in sentence-medial position, and ungrammatical word orders in terms of verb position (RQ1). In addition, we probe possible interactions between priming and modulating factors of CLI, namely partial word order overlap at the language level (RQ2), and proficiency differences at the learner level (RQ3).

The paper is structured as follows: We first discuss previous findings on the cross-linguistic priming of grammatical and ungrammatical word orders and then present approaches that conceptualize CLI as a form of cross-linguistic priming. To test their predictions, the following sections spell out the background of the present study and sketch word order differences between German and English as well as the research questions. We then review the patterns of CLI attested in German-English learners which we aim to replicate and enhance by virtue of cross-linguistic structural priming. In Study 1, we test low-proficiency adolescent L2 learners of English, and, in Study 2, we test L2 learners at later stages in their L2 development, that is, higher-proficiency adult L2 learners.

## Cross-linguistic priming of word order

Following research showing that language users reuse grammatical structures that they encountered before when speaking their first or second language (for review, Mahowald et al., 2016; for within-L2 priming, Jackson, 2018), studies on cross-linguistic structural priming demonstrate that the prior use of a grammatical structure in one language also facilitates its reuse in the other language in bilinguals. A large body of research attests that cross-linguistically shared constructions, such as word order options (e.g., passives, NP-modification), argument structure alternations (e.g., prepositional or dative objects of ditransitive verbs), or relative clause attachment options, can be primed across languages (for review, Van Gompel & Arai, 2018). Learners at lower proficiency show less priming, and priming seems to be more contingent on lexical overlap between primes and targets among beginning L2 learners (e.g., Schoonbaert et al., 2007). At higher proficiency, priming is more robust and it becomes more abstract in that L2 learners also demonstrate priming when there is no lexical overlap between primes and targets (e.g., Hartsuiker & Bernolet, 2017). Since cross-linguistic priming effects then obtain even when there is no phonological, semantic, and lexical overlap between prime structures and the subsequent target structures that speakers produce, there seems to be a structural component in that grammatical structures across languages are activated.

Most research on cross-linguistic priming has examined the cross-linguistic activation of structures that are grammatical in both the L1 and the L2 in order to show that learners develop cross-linguistically "shared" grammatical representations, as, for example, proposed in the Shared Syntax Model (Hartsuiker & Bernolet, 2017). There are fewer studies that investigate cross-linguistic priming of ungrammatical structures, that is, when a grammatical structure in one language is not shared with the same structure in the other language. Among young simultaneous bilingual

children, priming of L1 word order leads children to use this word order in their other language, even when it is ungrammatical in the latter. For instance, English-Spanish bilingual children aged 4–5 years produce significantly more ungrammatical prenominal attributive adjectives in Spanish following an English sentence with a prenominal attributive adjective than a neutral English sentence with a predicative adjective (Hsin et al., 2013). In a similar study, van Dijk and Unsworth (2022) also report that child bilinguals produce ungrammatical postnominal adjectives Dutch to larger degrees when primed with this word order in Spanish or French. These studies show that priming can elicit CLI at greater levels than would surface in (unprimed) production among child bilinguals.

To date, few studies have directly compared cross-linguistic priming of grammatical and ungrammatical word orders. Using visual-world eye-tracking, Hopp and Grüter (2021) investigated how German questions prime English questions in L2 comprehension. Critically, German object questions (1a) have the same surface word order as English subject questions (1b) but differ in word order from English object questions (1c). In consequence, the study examined (a) whether priming of ungrammatical object interpretations of English subject questions would obtain due to similar word order in (1a&b) and (b) whether priming of grammatical object interpretations would hold despite differences in word order between (1a) and (1c).

(1)  a. Welches Kamel beisst der Hund?
        Which camel bites the$_{NOM}$ dog
     b. Which camel bites the dog?
     c. Which camel does the dog bite?

Among intermediate proficiency German-English learners, German object questions facilitated the subsequent comprehension of object questions in English, yet there was no priming of ungrammatical object interpretations of English subject questions. These findings suggest that CLI during L2 sentence comprehension may play out differently for grammatical and ungrammatical L2 structures. However, the condition with word order overlap (1a&b) entailed different interpretations, so that CLI went beyond overlap in syntax in that study.

The present study focusses on word order overlap and systematically assesses patterns of cross-linguistic priming of grammatical and ungrammatical word orders in L2 production across a range of syntactic structures in order to delineate the degree to which cross-linguistic structural priming may constitute a mechanism underlying CLI.

## Mechanisms of cross-linguistic priming as CLI: Different accounts

Cross-linguistic structural priming and CLI share many characteristic features: First, cross-linguistic priming heightens the activation of the other language, which is likely to be a prerequisite for cross-linguistic influence to occur. Second, the strength of cross-linguistic structural priming appears to be affected by similar factors as CLI in unprimed production, that is, learners' proficiency levels and the degree of word

order overlap between languages. These parallels between priming and CLI have given rise to different proposals that cross-linguistic structural priming may be an underlying psycholinguistic mechanism of CLI at different levels.

First, CLI may be propelled by the continuous switching between languages – typical in bilinguals' language use – which leads to an increase in the activation level of the other language. In this respect, Serratrice (2016) argues that "the likelihood of ungrammatical or suboptimal structures in Language a – arising from the selection of syntactic operations from Language α – are going to be more likely to occur if the activation stage of Language α is high due to recent use" (Serratrice, 2016: 825). Such a global effect of priming in terms of language switching scopes over all properties of language, irrespective of whether they are specifically realized in the recent use of the other language.

Second, CLI may be the consequence of cross-linguistic activation of particular lexico-grammatical structures. In an adaptation of the lexicalist model of speech production by Hartsuiker et al. (2004), Nicoladis (2006, 2012) captures CLI as the competition between "two syntactic rules" (Nicoladis, 2006: 28) at the lemma level. When speakers choose a grammatical structure to express predicate-argument relations, for example, between a verb and its subject and object, they can opt for either the L1 or the L2 syntactic options. As a result, all grammatical structures linked to joint lemma entries in bilinguals are potentially subject to CLI. Such CLI will become stronger after recent use of the L1-based option, which heightens the resting activation of the competing structure. Nicoladis further hypothesizes that CLI should be the stronger the greater the lexical and phonological overlap is, since such overlap enhances the activation of L1 properties at the lemma level. In this sense, she conceives of CLI as an "epiphenomenon" of bilingual speech production, in which lexical candidates from all languages and their associated grammatical properties are activated and compete for selection. As a consequence, cross-linguistic priming should be restricted to the grammatical structures linked to shared lemma nodes between prime and target.

To adjudicate between the two approaches to CLI as priming, we examine different grammatical structures in German and English, some of which will be subject to cross-linguistic priming and others that are not included in the priming phase of the studies.

## English and German word order

In this study, we examine cross-linguistic priming and CLI across four aspects of word order variation between English and German. English has strict SVO word order (2a), which entails that the verb position relative to the subject does not change when other constituents are placed at the beginning of clauses (2b). In these cases, the verb surfaces in third position and cannot be in second position (2c). In the context of sentence-medial adverbs, the verb follows adverbs (2d) and cannot appear in front of the adverb (2e). Within transformational theories of syntax, this word order is a consequence of the lack of verb raising to a higher position in the clause (e.g., Chomsky, 1981). Finally, English has ordering preferences for adverbials in that locative phrases (LPs) precede temporal phrases (TPs; 2f). The reverse

order in (2g) is marked and requires discourse contexts in which the locative phrase represents new information for it to be pragmatically felicitous (e.g., Birner & Ward, 1998).

(2)  a. The man ate an apple last week.
    b. Last week the man ate an apple.
    c. *Last week ate the man an apple.
    d. The man often eats an apple.
    e. *The man eats often an apple.
    f. The man ate in the garden last week.
    g. #The man ate last week in the garden.

German has underlying SOV word order, which constitutes the canonical word order in embedded clauses (e.g., Haider, 2010). In main clauses, German displays verb-second (V2) word order, meaning that the finite verb always appears as the second constituent. In subject-first sentences, the German V2 word order is surface-identical to SVO in English (3a). However, with other clause-initial elements, there is subject-verb inversion in (3b) compared to (3a), and orders with the verb in third position, as in English, are ungrammatical (3c). The finite verb appears in front of sentence-medial adverbs, since German is a verb-raising language (3d), so that finite verbs never follow sentence-medial adverbs (3e). In sentences with multiple adverbials, German prefers TPs to precede LPs (3f vs 3g; e.g., Lenerz, 1977).

(3)  a. Der Mann aß letzte Woche einen Apfel.
      The man ate last week an apple
    b. Letzte Woche aß der Mann einen Apfel.
      Last week ate the man an apple
    c. *Letzte Woche der Mann aß einen Apfel.
      Last week the man ate an apple.
    d. Der Mann isst oft einen Apfel.
      The man eats often an apple
    e. *Der Mann oft isst einen Apfel
      The man often eats an apple
    f. Der Mann aß letzte Woche im Garten.
      The man ate last week in the garden
    g. #Der Mann aß im Garten letzte Woche.
      The man ate in the garden last week

Table 1 provides an overview of the word order (dis)similarities between English and German. When comparing the word order options in English and German, one finds that they align along a cline of well-formedness of grammatical, dispreferred, and ungrammatical orders in English versus German (4). Adverbial fronting is a licit option in both languages, TP-LP orders of sentence-medial adverbials are possible in English, although dispreferred, and V2 and verb raising are ungrammatical options in English declaratives.

**Table 1.** Word orders in English and German in different structures.

|  | English | German |
|---|---|---|
| Subject-first sentences (2a&3a) | S**V**O | S**V**O (= V2) |
| Adverbial fronting (2b&3b) | **Adv**-clause | **Adv**-clause |
| Verb position with adverbial fronting (2b&3b) | Adv-S**V**O | Adv-**V**SO |
| Verb raising across adverbs (2d&3d) | Adv-**V** | **V**-Adv |
| Sentence-medial adverbial order (2f&3f) | LP-TP | TP-LP |

(4) Adverbial fronting (optional) < TP-LP order (dispreferred) < V2 & verb raising (ungrammatical)

Further, for ungrammatical V2, English and German exhibit different degrees of word order overlap. In questions, English displays "residual V2" (Rizzi, 1996) in that auxiliaries and light verbs, yet not lexical or thematic verbs, appear in second position after the fronted wh-phrase (*What is the man eating?/Where is the man?* vs *\*What eats the man?/\*Where sleeps John?*). Similarly, negative and stylistic inversion implicates V2 for auxiliaries in English (*Never has he seen a dog as unruly as this one*). In contrast, full inversion with thematic verbs is much less common in English and largely restricted to locative and quotative inversion (e.g., Bresnan, 1994) when the verb is informationally light (Birner, 1995). This asymmetry in availability and frequency of V2 in English between light and thematic verbs leads to partial word order overlap between English and German for V2 with copula, modal, and auxiliary verbs, on the one hand, but no word order overlap for thematic verbs, on the other.

## Cross-linguistic influence of word order in German-English learners

Bilingual children, as well as late L2 learners of English, show CLI for all four grammatical structures under consideration in language comprehension and production, though to different degrees. As for the cross-linguistically licit option of adverbial fronting, German-English as well as English-German learners use fronted adverbials in their L2s. Yet, L1 English learners of German start to front adverbials in German later and less often (e.g., Jackson & Ruf, 2017) than L1 German learners of English (e.g., Jackson & Hopp, 2020), suggesting that there is cross-linguistic influence in how often learners resort to fronting in L2 production (see also Carroll et al., 2000; O'Brien & Féry, 2015; for comprehension, see Hopp et al., 2020).

As for ungrammatical V2, simultaneous German-English children sometimes produce V2 orders in English (Döpke, 1998; for Norwegian-English, see Anderssen et al., 2018), and, for example, Dutch-English bilingual children over accept V2 orders in English sentences (Bosch & Unsworth, 2021). In both production and comprehension, the use of V2 in English is higher for sentences with auxiliary verbs than with main verbs, at least for some children (Döpke, 1998). Such an asymmetry has been linked to the partial word order overlap between V2 languages and English for light verbs. Bilingual children are sensitive to these cross-linguistic

differences in word order according to verb type in that they allow for V2 more often for auxiliaries and copula verbs (Bosch & Unsworth, 2021).

For sequential late L2 learners, proficiency affects the amount of ungrammatical V2 in English in that lower-proficiency L2 English learners produce more V2 compared to higher-proficiency learners (for German-English, Kaltenbacher, 2001; Weigl, 1999; for Dutch-French, Hulk, 1991; for Norwegian-English, Westergaard, 2003). They also produce more V2 word orders in written sentence production with auxiliaries and light verbs than with thematic verbs (e.g., Rankin, 2009, 2012; for Norwegian-English learners, Westergaard, 2003), and they accept V2 more for auxiliary than thematic verbs, in particular when the verb follows a fronted adverbial (Sorace & Robertson, 1999). In a corpus study of classroom discourse in foreign-language lessons of L2 English in German primary and secondary schools, Rankin (2022) reports that L2 learners encounter significantly more instances of V2 with auxiliary and modal verbs than with thematic verbs. In turn, L2 learners appear to be sensitive to these frequency differences in V2 according to verb type, and they inflect their productions of ungrammatical V2 orders in L2 English accordingly.

In sum, both early bilinguals and sequential L2 learners show CLI in word order across the different phenomena investigated in this study, especially at lower levels of L2 proficiency. At the same time, the extent of CLI is affected by the grammatical properties of these structures, their word order overlap in L1 and L2, and the frequency of their occurrence in the L2. Against this backdrop, we investigate whether and how cross-linguistic structural priming, that is, the immediate prior use of L1 grammatical structures, (a) amplifies the amount of CLI for each of these phenomena in German-English L2 learners and (b) whether priming is modulated by the same factors as CLI in unprimed production.

## Research questions

In two priming studies that each consist of a pretest, a priming task, and a posttest, we examine four grammatical structures in the L1, namely the fronting of temporal adverbials, the relative order of temporal and locative adverbials, and the use of verb second and verb raising across adverbs. The first three of these structures are embedded in the priming task, whereas verb raising across adverbs is not included in the priming task, allowing us to assess in the posttest whether changes in CLI from German to English as a result of the activation of German in priming task are restricted to the structures contained within the priming task.

We address the following general research question.

> (GQ) Can cross-linguistic influence be enhanced by cross-linguistic structural priming?

We investigate effects of priming on CLI in two ways. First, we consider trial-to-trial priming by examining whether speakers immediately use L1-based structures after listening to and repeating L1 sentences containing these structures in a cross-linguistic structural priming task. Second, we explore longer-term priming effects in the posttest, that is, an L2-only production task following the priming task.

Comparing short-term and longer-term priming affords insights into the longevity of CLI through priming and can thus adjudicate between different approaches to priming as an underlying mechanism that drives CLI. If CLI results from the global activation of the resting state of the L1 in language switching contexts (e.g., Serratrice, 2016), we would expect to see greater CLI in short-term priming, yet less longer-term priming of CLI that persists into later (English-only) production, since the global activation of the L1 subsides rapidly once it is no longer used. Furthermore, due to the global activation of the L1, cross-linguistic priming should lead to an increase in CLI beyond the specific L1 structures that are presented in priming and thus affect all four structures tested, with each individual structure showing priming.

If CLI arises as the consequence of the cross-linguistic co-activation of specific lexico-grammatical connections in language production (Nicoladis, 2006), priming should be restricted to the three structures presented in the priming task, yet not extend to ungrammatical verb raising. In addition, since the resting level of activation of specific structures will be augmented each time they are activated, we would expect to see CLI in both short-term and longer-term priming.

Specifically, we address the following three specific research questions and test each individual hypothesis associated with the respective research question.

(RQ1) How does well-formedness modulate CLI in the context of cross-linguistic structural priming?

The four grammatical structures in the L1 differ in their well-formedness in the L2. The fronting of temporal adverbials constitutes a licit option in both German and English. The relative order of temporal and locative adverbials represents a structure where the preferred order in German corresponds to the dispreferred – but not ungrammatical – order in English. Finally, verb second and verb raising, which are obligatory in German, lead to ungrammatical structures in English declaratives. Since all of these structures have been found to be subject to CLI in L1 German L2 learners of English, if cross-linguistic priming is a general mechanism of CLI, we expect to see priming in each of the four individual structures, including ungrammatical options.

(RQ2) How does word order overlap modulate CLI in the context of cross-linguistic structural priming?

This study manipulates the type of verb to examine the role of partial word order overlap that affects the degree of CLI with verb second (Bosch & Unsworth, 2021; Hulk & Müller, 2000). To this end, the studies use copula verbs (*be*) and lexical-thematic verbs (e.g., *play*). For copula verbs, English displays verb second in question and stylistic inversion, while verb second for thematic verbs is not attested in English, except for locative and quotative inversion. Learners produce more verb second for copula and auxiliary verbs than for thematic verbs (e.g., Rankin, 2012; Westergaard, 2003), suggesting that partial word order overlap leads to more CLI in (unprimed) L2 production. Since partially overlapping structures are subject to more CLI, we hypothesize that word order overlap with the L1 should boost

**Table 2.** Study 1: Participant characteristics ($n = 32$). Standard deviations are in parentheses

|  | Mean (SD) | Range |
|---|---|---|
| Age at Testing (yrs) | 13.0 (0.5) | 12.3-14.3 |
| Age of Onset (yrs) | 7.9 (0.4) | 7-9 |
| Length of Exposure (yrs) | 4.7 (0.4) | 2.7-4.4 |
| Proficiency (CLT; max = 32) | 18.4 (3.1) | 13-28 |

cross-linguistic priming for verb second for copula compared to thematic verbs. In consequence, there should be a significant interaction of priming with verb type in the analysis for verb-second structures.

> (RQ3) How does L2 proficiency affect CLI under conditions of cross-linguistic priming?

We test low-intermediate adolescent L2 learners in Study 1, and more proficient adult L2 learners in Study 2, based on the rationale that the adult L2 learners in Experiment 2 conceptually represent the learners in Experiment 1 at a later stage in their L2 development. Further, we examine effects of proficiency as a continuous variable within the larger sample of participants in Study 2. L2 proficiency is known to predicate the extent of CLI, that is, the degree of L1-based word orders in unprimed production. In turn, the degree of priming should be larger for speakers who produce more L1-based structures in L2 English, since the activation level of these L1 structures is higher when they use the L2. We thus predict an interaction of priming with proficiency in each individual structure.

## Study 1
### *Participants*
Thirty-four adolescent learners of English were tested (21 female; $M_{age} = 13.0$ yrs; $SD = 0.5$) who were all dominant speakers of L1 German. We excluded two participants who stated that they had learned English alongside German from birth. Five participants spoke a heritage language on top of German at home (Russian, Turkish, Arabic, and Italian). All participants were students at public German schools in 7th or 8th grade and had had English as foreign-language lessons since 3rd grade ($M_{Exposure} = 4.7$ yrs; $SD = 0.4$). Table 2 summarizes the participant characteristics. Proficiency in English was assessed using a picture naming task of high-frequency English words (Cross-linguistic Lexical Task – CLT; Haman et al., 2015) that was appropriate to the developmental level of the participants. Participants scored in the low-intermediate range, with 30 participants scoring 22 or lower correct out of 30 items.

### Materials

*Baseline and posttest*

For baseline and posttest, twenty-four items with sentence fragments were constructed, containing an inflected verb (12 copula verbs - *is*, 12 thematic verbs – e.g., *drinks*), an animate, definite subject (e.g., *the waiter*), one locative PP adverbial (e.g., *in the restaurant*), and one temporal PP adverbial (e.g., *on Thursday*). In addition, twelve items contained a thematic verb, an animate subject, a definite object (e.g., *the news*), and a sentence-medial adverb (*always, often, never*). Finally, twelve filler sentences with locative PPs were used, half of which used *be* as a main verb with adjectives or intransitive verbs and the other half contained thematic transitive verbs. We created two lists for baseline and posttest each in which copula and thematic verbs were exchanged.
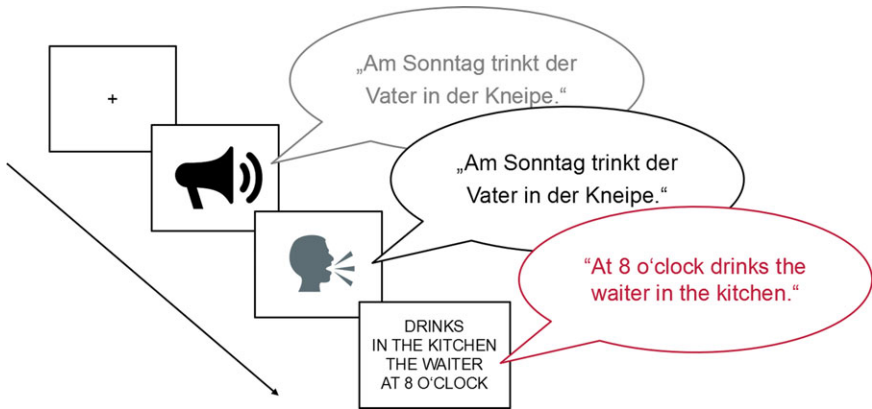
*Priming task*

For the priming task, we crossed the factors word order (fronted adverbial vs non-fronted adverbials) and verb type (copula vs thematic) in a $2 \times 2$ factorial design. As in the baseline and posttest, each sentence contained an animate, definite subject, and one temporal adverbial phrase (TP) and one adverbial locative phrase (LP), respectively. For fronting, we chose to front only TPs in the prime sentences, since this is the more frequent option in both English and German. A quadruplet of the prime sentences is shown in (5&6).

(5)  a. Am Sonntag ist der Vater in der Kneipe. (fronted, copula verb)
          On Sunday is the father in the pub.
     b. Der Vater ist am Sonntag in der Kneipe. (non-fronted, copula verb)
          The father is on Sunday in the pub.
(6)  a. Am Sonntag trinkt der Vater in der Kneipe. (fronted, thematic verb)
          On Sunday drinks the father in the pub.
     b. Der Vater trinkt am Sonntag in der Kneipe. (non-fronted, thematic verb)
          The father drinks on Sunday in the pub.

There were eight items per condition, totaling 32 experimental items, which were presented alongside 48 filler sentences in four different lists. The filler sentences contained transitive and ditransitive verbs in the prime sentences. Half of the fillers showed verb overlap between prime and target. Figure 1 presents a schematic visualization of the sequence and format in which the priming task was presented.

Following the prime sentence, participants were presented with sentence fragments that constituted the target sentence. Target sentence fragments contained the same elements as in the baseline and posttest. For the target sentences, we used the same verb as in the preceding prime, that is, *is* for copula verbs and the respective thematic verb, for example, *drinks*. We decided to reuse the English translation equivalents of the prime verbs to maximize overlap so as to increase priming effects, especially among lower-proficiency L2 learners who show (more) priming under lexical overlap (Hartsuiker & Bernolet, 2017). The other words in the sentences had different lexicalizations compared to the prime sentence, as shown in Figure 1.

**Figure 1.** Sequence and Presentation of Priming Task in Study 1 for German Prime (6a) and English Target.

As seen in Figure 1, for all task phases (baseline, priming phase, and posttest), the sentence fragments were presented in vertical order in a display. The verb was always the first element across all tasks. The order of the following elements was randomized, such that there was an equal number of displays that had the subject, the locative or temporal adverbial in lines 2–4. Participants were instructed to produce a sentence by ordering the fragments to form a grammatical sentence in English. Baseline and posttest consisted only of the displays with the sentence fragments; no prime sentence was involved.

### Procedure

Participants completed the experiment in a quiet laboratory on a computer using E-Prime 2.0 (Schneider et al., 2002). Participants' responses for the baseline, priming, and posttest tasks were recorded with a digital recorder. Participants first completed the baseline task. The experimenter read the instructions aloud to the participant, and they were also displayed on the computer screen. Each trial began with a fixation point "+" for 500 ms. After the fixation point disappeared, the display with the sentence fragments appeared for 10 seconds, and participants were instructed to rearrange the fragments to form a grammatical sentence in English. Participants could complete the sentence even after the display changed to a blank screen. The experimenter then clicked the mouse to proceed to the following trial. Participants had two practice trials at the beginning of the task. Following the baseline task, participants completed the priming task. As shown in Figure 1, each trial also began with a fixation point for 500 ms. When the fixation point disappeared, participants listened to a German (prime) sentence, spoken by a female native speaker of German. When the screen changed, the participants repeated the sentence verbatim. We asked participants to repeat the prime sentence, since prime repetition has been found to increase priming effects, in particular among less-proficient L2 speakers (e.g., Jackson & Ruf, 2018). Subsequent to their production, the experimenter initiated the presentation of the display with the English sentence

fragments for the target sentence. Again, participants had 10 seconds to form a sentence, until the screen changed. As before, participants could complete the sentence even after the fragments disappeared. The experimenter then clicked the mouse to proceed to the following trial. Participants took four practice trials at the beginning of the task to make sure they understood all components of the task. Following the priming task, participants completed the posttest. It had the same procedure as the baseline task, yet did not include any practice items.

### Results

Participants' responses in the baseline, priming, and posttest tasks were transcribed verbatim and scored as follows. (A) Fronted vs non-fronted adverbial for all sentences: Here, we only consider whether an adverbial was in sentence-initial position, irrespective of the word order in the rest of the sentence. (B) V2 or non-V2 for all fronted: Here, we only consider the fronted sentences, as they show a clear difference between V2 (Adv-V-S) and V3 (Adv-S-V) structures. By contrast, subject-initial sentences are uninformative, since SVO and V2 both lead to the same surface word order. Hence, our assessment of V2 word order is contingent on learners producing fronted adverbials. (C) The relative order of TP and LP for all non-fronted sentences: Here, we only consider non-fronted sentences, since this is where TP and LP directly follow each other. (D) Verb-raising: In the baseline and posttest, the sentences with sentence-medial adverbs were scored for whether the verb preceded or followed the adverb (± verb raising).

Incomplete sentences were treated as missing data; this led to the removal of 14 out of 1152 items in the baseline, 15 out of 1024 target items in the priming task, and one out of 1152 items in the posttest. When participants made false starts or corrected themselves, we used the final version of the sentence they produced as the basis for our scoring. Analyses were conducted using mixed-effect logistic regression models with the *lme4* package in *R* version 4.0.2 (R Development Core Team, 2018). For all analyses reported here, the random effects structure included random intercepts for participants and items and all random slopes justified by the design. We used the "order" command in the *buildmer* package (Voeten, 2022) to determine the maximal model that would converge. Fixed effects were deviation-coded, and continuous fixed predictors were scaled and centered, as described below for each of the tasks.[1]

### Baseline task

We first assess the degree of CLI in the unprimed production of English sentences at baseline. Figure 1 graphs the proportion of sentences with fronted adverbials out of all sentences, the TP-LP orders produced in all sentences without fronted adverbials, and the sentences with ungrammatical V2 for all sentences with fronted adverbials. In addition, it plots the proportion of sentences with postverbal medial adverbs. For the first three types of word order variations, results are broken down by verb type of the sentences, even though effects of verb type are only tested for the V2 sentences.

At baseline, the participants produced a large number of adverbial frontings (258/754; $M = 33.6\%$; $SD = 34.0$), which were supplied by twenty-eight of the

32 participants. As for CLI from German, they produced many sentences with the dispreferred TP-LP order in non-fronted sentences (165/496; $M = 32.1\%$; $SD = 26.7$), which was produced by 28 participants. Among the sentences with fronted adverbials, participants also produced ungrammatical V2 sentences (48/258; $M = 17.0\%$; $SD = 31.3$). Thirteen out of the 28 participants who fronted adverbials used ungrammatical V2 orders. There was a significant difference between V2 sentences with copula verbs (38/132; $M = 26.1\%$; $SD = 37.6$) and with thematic verbs (10/126; $M = 7.8\%$; $SD = 25.0$; $\beta = 2.355$, $SE = 0.575$; $t = -4.095$; $p < .001$). For the control items with medial adverbs, 19 of 32 participants produced ungrammatical sentences with verb raising (70/336; $M = 18.2\%$; $SD = 21.0$). We checked whether proficiency affects the production of these word orders. There were no significant correlations between the CLT score and the proportion of sentences with fronted adverbials ($r = .102$), verb-second orders ($r = -.233$), or TP-LP orders ($r = -.167$). Ungrammatical verb raising across medial adverbs was correlated with proficiency ($r = -.494$); in that higher proficiency led to fewer instances of verb raising. Since none of the orders that would occur in the priming task were associated with proficiency at baseline, we analyzed the results at the group level and did not include CLT scores in the primary analysis.[2]

In sum, the baseline results bear out clear traces of CLI from German, as the L2 learners produce grammatical, dispreferred, and ungrammatical orders in English that are canonical or preferred orders in German at sizeable degrees.

*Priming task*
For the priming task, Table 3 charts the word orders produced by the participants in absolute and relative frequencies, and it presents the priming effect as the difference between the respective priming and the no-priming conditions.

As can be seen in Table 3, participants produced more target sentences with fronted adverbials following prime sentences with fronted adverbials. Among the subset of target sentences with non-fronted adverbials, there was a smaller proportion of TL-LP orders following prime sentences with non-fronted adverbials. For ungrammatical V2, the production of sentences with fronted adverbials and V2 word order was higher after prime sentences with fronted adverbials. To assess priming effects for the fronting of adverbials and TP-LP orders, we ran a mixed effects logistic regression models with Prime Type (fronted, .5; non-fronted, −.5) as a deviation-coded fixed effect. For priming effects on V2, we added the fixed effect of Verb Type (copula, −.5; thematic, .5) to the model. Using the "order" command in the *buildmer* package (Voeten, 2022) in *R*, version 4.02. (R Developmental Team, 2018), we identified the maximal model that converged. The outputs of these models are reported in Table 4.

For adverbial fronting, the model included all target sentences from the priming task. It returned a main effect of Prime Type, because participants produced more fronted adverbials after prime sentences that had fronted adverbials. In total, 22 participants produced fronted adverbials in the priming task. For TP-LP orders, the model included the subset of target sentence data that were not fronted. In total, 27 participants produced TP-LP orders. This model returned no significant effects.

**Table 3.** Study 1: Absolute frequencies and proportions of word orders averaged across participants produced by verb type. Standard deviations are in parentheses. ($n = 32$).

| Fronted Prime | Condition | Fronted adverbials in target utterances | Priming Effect | TP-LP orders in non-fronted target utterances | Priming Effect | V2 orders in fronted target utterances | Priming Effect |
|---|---|---|---|---|---|---|---|
| Yes | All verbs | 182/502 | **24** | 95/323 | | 23/182 | **14** |
| | | 35.9% (39.2) | **4.7%** | 25.6% (29.5) | | 10.4% (24.7) | **4.4%** |
| No | All verbs | 158/507 | | 102/349 | **7** | 9/158 | |
| | | 31.2% (38.5) | | 27.7% (32.0) | **2.1%** | 6.0% (21.3) | |
| Yes | Copula verb | 93/255 | | 56/162 | | 17/93 | **10** |
| | | 36.3% (39.6) | | 26.6% (28.2) | | 16.5% (31.8) | **5.5%** |
| | Thematic verb | 89/250 | | 39/161 | | 6/89 | **4** |
| | | 35.4% (38.8) | | 24.7% (30.8) | | 4.2% (11.2) | **3.3%** |
| No | Copula verb | 84/252 | | 47/168 | | 7/84 | |
| | | 33.1% (40.0) | | 26.3% (30.8) | | 11.0% (29.1) | |
| | Thematic verb | 74/255 | | 55/181 | | 2/74 | |
| | | 29.3% (36.9) | | 29.2% (33.2) | | 0.9% (3.8) | |

**Table 4.** Study 1: Priming Task ($n = 32$).

| Variable | | Estimate | SE | t | p |
|---|---|---|---|---|---|
| Adverbial Fronting | Intercept | −1.948 | 0.711 | −2.738 | .006 |
| | **Prime Type** | **−0.288** | **0.106** | **−2.713** | **.007** |
| | Formula: ADV-Fronting ~ 1 + Prime Type + (1 \| Subject) + (1 \| Item) | | | | |
| TP-LP orders | Intercept | −1.271 | 0.337 | −3.770 | <.001 |
| | Prime Type | −0.100 | 0.125 | −0.802 | .422 |
| | Formula: TP-LP ~ 1 + Prime Type + (1 + Prime Type \| Subject) + (1 \| Item) | | | | |
| V2 | Intercept | −2.883 | 0.625 | −4.617 | <.001 |
| | Prime Type | −0.361 | 0.273 | −1.322 | .186 |
| | **Verb Type** | **0.745** | **0.280** | **2.658** | **.008** |
| | Prime Type*Verb Type | −0.058 | 0.273 | −0.213 | .831 |
| | Formula: V2 ~ 1 + Verb Type + Verb Type:Prime Type + (1 \| Subject) + (1 \| Item) | | | | |

Finally, to assess effects of priming on the production of ungrammatical V2, we constructed the same models with V2 as the dependent variable for all target sentences produced with fronted adverbials, including the factor Verb Type. As seen in Table 4, only the main effect of Verb Type reached significance, with more V2 sentences being produced for copula (24/177) than thematic verbs (8/163). Despite the strong numerical trend towards a higher number of V2 following prime sentences with fronted adverbials (23/182) compared to sentences without fronted adverbials (9/158), the main effect of Prime Type was not significant. This may reflect the uneven distribution of V2 productions, since only 13 participants of the 22 who produced fronted adverbials also produced sentences with ungrammatical verb-second orders.

In sum, the group demonstrated significant priming for fronted adverbials following fronted prime sentences. For V2, the numerical trend for priming of ungrammatical V2 utterances was not significant. Instead, as in the baseline, V2 was produced significantly more often in sentences with copula verbs, regardless of prime type.

### Posttest

To assess whether CLI in production changed from baseline to the posttest, we constructed a model with Task (baseline, −.5; posttest, .5) and, for Verb Second, Verb Type (copula, −.5; thematic, .5) and its interaction as fixed effects, and we included their interaction as a random slope on the intercept term by participant. The outputs of the maximal models returned by the *buildmer* function are given in Table 5.

For fronted adverbials, there was no change from baseline to posttest (mean difference: 1.0%; see also Figure 2). For TP-LP orders, the main effect of Task reflects the reduction from pretest (165/496; $M = 32.1\%$; $SD = 26.7$) to posttest

**Table 5.** Study 1: Baseline to Posttest ($n = 32$).

| Variable | | Estimate | SE | t | p |
|---|---|---|---|---|---|
| Adverbial Fronting | Intercept | −1.382 | 0.484 | −2.854 | .004 |
| | Task | −0.049 | 0.077 | −0.641 | .521 |
| | Formula: ADV−Fronting ~ 1 + Task + (1 \| Subject) + (1 \| Item) | | | | |
| TP-LP orders | Intercept | −1.157 | 0.308 | −3.758 | <.001 |
| | **Task** | **0.272** | **0.108** | **2.515** | **.012** |
| | Formula: TP−LP ~ 1 + Task + (1 + Task + Verb Type \| Subject) + (1 \| Item) | | | | |
| V2 | Intercept | −2.927 | 0.648 | −4.516 | <.001 |
| | Task | 0.462 | 0.378 | 1.223 | .221 |
| | **Verb Type** | **−1.146** | **0.433** | **−2.645** | **.008** |
| | **Task*Verb Type** | **−1.139** | **0.431** | **−2.642** | **.008** |
| | Formula: V2 ~ 1 + Task + Verb Type + Task:Verb Type + (1 + Task \| Subject) + (1 \| Item) | | | | |
| Verb raising | Intercept | −2.192 | 0.389 | −5.633 | <.001 |
| | Task | −0.087 | 0.176 | −0.493 | .622 |
| | Formula: Verb-Raising ~ 1 + Task + (1 + Task \| Subject) + (1 \| Item) | | | | |

(136/497; $M = 24.9\%$; $SD = 29.9$; mean difference $= −7.2\%$). For sentences with ungrammatical V2, there was a reduction from 26.1% (38/132) to 7.6% (6/139) for sentences with copula verbs (mean difference $= −18.5\%$) and from 7.8% (10/126) to 1.8% (5/131) for sentences with thematic verbs (mean difference $= −6.0\%$). The difference in change depending on verb type is reflected in the interaction between Task and Verb Type, which bears out that the effect of Task was more pronounced for copula verbs ($\beta = 1.316$, $SE = 0.326$; $t = 4.038$; $p < .001$) than for thematic verbs ($\beta = 3.286$, $SE = 1.530$; $t = 2.147$; $p = .032$). Finally, for verb raising across medial adverbs, there was no significant change from pretest (70/336; $M = 18.2\%$) to posttest (61/333; $M = 15.9\%$; mean difference $= −2.3\%$).

## Discussion

In Study 1, we assessed the degree to which cross-linguistic priming leads to greater CLI across different L1-based word orders in L2 English among low-proficiency L2 learners. At baseline, the participants produced a sizeable amount of L1-based word orders, including dispreferred TP-LP orders as well as ungrammatical verb-second orders and sentences with verb raising across medial adverbs. These findings document robust CLI from German in L2 English sentence production. As in previous research on (unprimed) L2 learners (Rankin, 2012; Westergaard, 2003) and bilingual children (Bosch & Unsworth, 2021), such CLI was modulated by partial word order overlap between German and English in that the proportion of V2 orders with copula verbs was significantly higher than with thematic verbs.
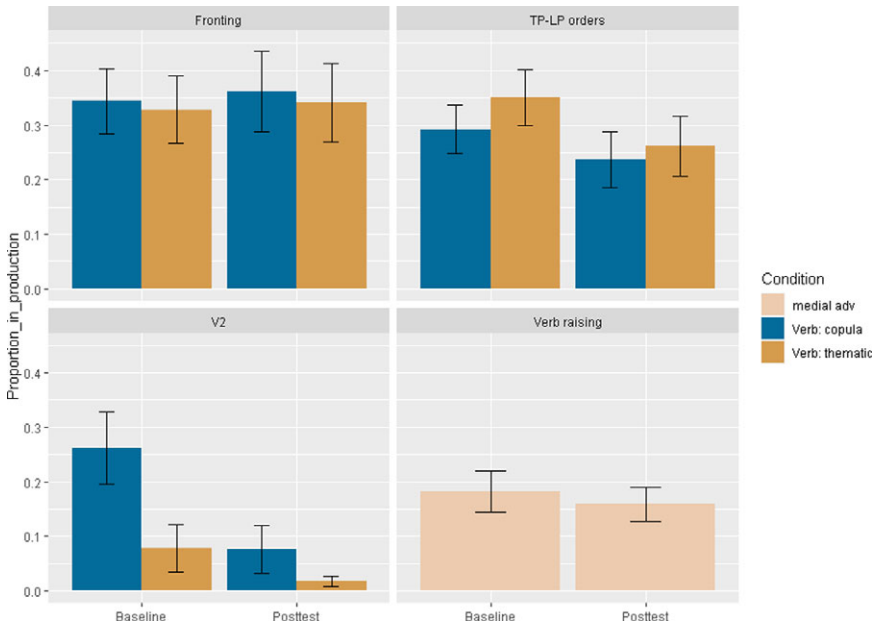
**Figure 2.** Study 1: Baseline and Posttest: Proportions of Word Orders Produced by Verb Type. Error Bars Show the Standard Error of the Mean. ($n = 32$).

In the priming task, the participants demonstrated significant priming of fronted adverbials. This effect demonstrates that the task is successful in eliciting cross-linguistic priming of grammatical structures that are well-formed in both the L1 and the L2. In the posttest, the group did not produce more sentences with fronted adverbials than at baseline, despite the significant priming of fronted adverbials in the priming task. In this respect, the present data are comparable to asymmetries in within-L2 priming between short-term priming and the absence of longer-term priming in beginning to intermediate L1 English learners of German (Jackson & Ruf, 2017), yet different from studies with more highly proficient L1 German learners of English (Jackson & Hopp, 2020), who demonstrated both short-term and longer-term priming. In this regard, the present findings bolster previous proposals that L2 learners at lower proficiency may use explicit memory strategies in the priming task, in particular when there is verb overlap between primes and targets, as in the present study (see Hartsuiker & Bernolet, 2017).

In all, Study 1 showed significant cross-linguistic priming only for optional and grammatical word orders, that is, adverbial fronting. For dispreferred TP-LP order and ungrammatical V2 word orders, participants did not overall produce more of these orders following German prime sentences that overtly displayed these surface word orders. For TP-LP orders, participants produced a comparable proportion of TP-LP orders in the midfield in the priming task ($M = 33.7\%$) and at baseline ($M = 32.1\%$); however, the number was lower in the posttest ($M = 24.9\%$). Despite a strong numerical trend, German prime sentences with fronted adverbials that displayed V2 orders did not result in significant priming of ungrammatical V2

utterances in English. Instead, the overall proportion of ungrammatical V2 orders was considerably lower in the priming task (32/340 = 9.7%) than at baseline (48/258 = 18.6%) and even less in the posttest (11/277 = 4.0%).

In sum, the study demonstrates that cross-linguistic priming affects CLI asymmetrically in raising the production from baseline to posttest of grammatical and shared word order options in L1 and L2 and in lowering the production of L1-based word orders that are dispreferred or ungrammatical in the L2. Of note, these reductions did not obtain for an ungrammatical structure, verb raising, which the learners did not encounter during the priming phase. Such an asymmetry suggests that cross-linguistic priming affects the L2 production only of structures that had been activated in the L1, which, in turn, leads to an increasing differentiation of L1 and L2 grammatical structures in L2 production.

However, the participants in Study 1 exhibited only short-term priming with fronted adverbials. We attribute the lack of longer-term priming to the low proficiency of the learners, which may have limited priming to explicit memory strategies. Hence, the scope of priming to occasion CLI in the longer run may be circumscribed by the strategies low-proficiency learners use in L2 production. To address this possibility, we adapted the study for learners at a later point in their learning trajectory, that is, more advanced L2 learners at higher proficiency, who likely demonstrate greater and longer-lasting cross-linguistic structural priming. This way, we can test whether effects of cross-linguistic structural priming on CLI with dispreferred and ungrammatical orders emerge during L2 development once learners show longer-lasting cross-linguistic priming for optional word orders in general. Since proficiency is known to affect the degree of CLI among adult L2 learners, Study 2 tests a larger group of more advanced L2 learners at different levels of proficiency.

## Study 2

### Participants

Sixty learners of English were tested (46 female; $M_{age}$ = 21.8 yrs; $SD$ = 2.9) who were all dominant speakers of L1 German. Three participants spoke a heritage language on top of German at home (Bosnian, Polish). The participants had comparable ages of onset to English as the participants in Experiment 1, but were further along in their L2 development. At the time of testing, all participants were adult students at a public German university. Table 6 summarizes the participant characteristics. Proficiency in English was assessed using the LexTALE task (Lemhöfer & Broersma, 2012), an untimed lexical decision task that was normed relative to standardized proficiency tests.[3] Participants' scores fell into the mid-intermediate to advanced range.

### Materials and procedure

The materials were largely identical to those in Study 1, except for several vocabulary items that were adapted for the study with adults. In contrast to Study 1, the sentence fragments that were displayed on the screen in all three tasks did not

**Table 6.** Study 2: Participant characteristics ($n = 60$). Standard deviations are in parentheses

|  | Mean (SD) | Range |
|---|---|---|
| Age at Testing (yrs) | 21.8 (0.5) | 17–32 |
| Age of Onset (yrs) | 8.3 (1.8) | 5–11 |
| Length of Exposure (yrs) | 13.6 (3.1) | 8–23 |
| Proficiency (LexTALE; max = 100%) | 70.8 (12.8) | 48.8–96.3 |

contain articles and prepositions to make the task more challenging for more advanced learners. Given that participants needed to add these elements when producing full sentences, the tasks presented the displays until the participants had completed the sentence.

## Results

### Baseline

As seen in Figure 3, the participants produced a large number of adverbial frontings (367/1413; $M = 26.0\%$; $SD = 28$). Forty-four of the 60 participants produced sentences with fronted adverbials. As for CLI from German, in non-fronted sentences, participants also produced the dispreferred TP-LP order (147/1046; $M = 14.6\%$; $SD = 23$), with 36 participants producing such orders. Among the sentences with fronted adverbials, participants produced a low proportion of ungrammatical V2 sentences, which differed between sentences with copula verbs (13/190; $M = 7.1\%$; $SD = 20$) and with thematic verbs (2/177; $M = 2.5\%$; $SD = 25.9$; $\beta = -2.457$, $SE = 1.021$; $t = -2.406$; $p = .016$). Twelve out of the forty-four participants who fronted adverbials used ungrammatical V2 orders. For the control items with medial adverbs, participants also produced ungrammatical sentences with verb raising (48/717; $M = 6.7\%$; $SD = 14$). Eighteen of the sixty participants produced verb raising. These overall numbers demonstrate some CLI from the L1, albeit at low levels.

Next, we tested whether proficiency affected the production of these word orders. There were no significant correlations between the LexTALE score and the proportions of fronted adverbials ($r = -.007$), verb-second orders ($r = -.156$); yet, the proportion of TP-LP orders ($r = -.264$) and ungrammatical verb raising were correlated with proficiency ($r = -.357$) in that higher proficiency led to fewer instances of these L1-based word orders in production. As a consequence, we used proficiency score as a fixed effect in the analysis of the priming task.

### Priming task

For the priming task, Table 7 charts the word orders produced by the participants in absolute and relative frequencies and the priming effect as a difference score.

As seen in Table 7 for copula verbs, participants produced more target sentences with fronted adverbials following prime sentences with fronted adverbials. In contrast, there was no priming for dispreferred TP-LP orders or ungrammatical V2,
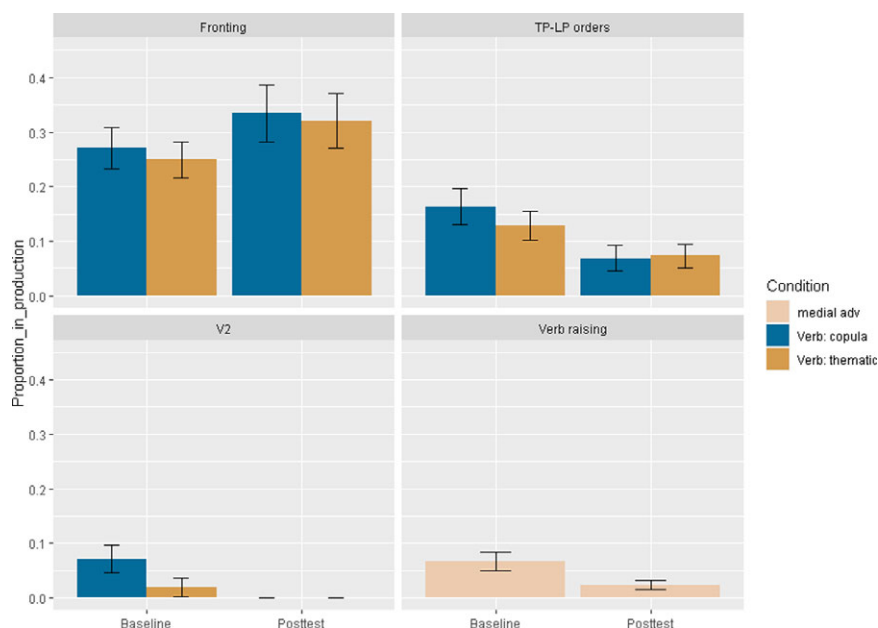
**Figure 3.** Study 2: Baseline and Posttest: Proportions of Word Orders Produced by Verb Type. Error Bars Show the Standard Error of the Mean. ($n = 60$).

which was produced only very rarely. As in Study 1, we ran a mixed effects logistic regression model with Prime Type (non-fronted, $-.5$; fronted, $.5$) as a deviation-coded fixed effect for each word order. In addition, we included interactions with proficiency (LexTALE score) as a scaled and centered predictor. The outputs are reported in Table 8. Since there were only six V2 productions among the 680 fronted sentences in total, produced by five learners in the priming task altogether, with a priming effect of 0%, we did not run a model for verb second due to data sparsity (Jaeger, 2008).

For adverbial fronting, the model did not return an effect of Prime Type, even though more fronted adverbials were produced after fronted primes for copula verbs (priming effect $= 6.5\%$). In fact, a separate model for copula verbs returns a significant effect of Prime Type ($\beta = -0.394$; $SE = 0.138$; $t = -2.850$; $p = .004$). There were no effects or interactions with proficiency. Overall, 46 of the 60 participants produced fronted adverbials in the priming task. For TP-LP orders, the model only returned a main effect of proficiency, signaling that dispreferred TP-LP orders were produced less often by more highly proficient L2 learners. Overall, 25 participants produced TP-LP orders in the priming task. Finally, there was no priming of ungrammatical V2 orders.

*Posttest*
To assess whether CLI in production changed from baseline to the posttest, we ran the same analyses as in Study 1. The outputs of the maximal models returned by the

**Table 7.** Study 2: Priming Task: Absolute frequencies and proportions of word orders across participants produced by verb type. Standard deviations are in parentheses. (n = 60).

| Fronted Prime | Condition | Fronted adverbials in target utterances | Priming Effect | TP-LP orders in non-fronted target utterances | Priming Effect | V2 orders in fronted target utterances | Priming Effect |
|---|---|---|---|---|---|---|---|
| Yes | All verbs | 343/958 | **−6** | 70/615 | | 3/343 | **0** |
| | | 35.8% (37.7) | **−0.7%** | 9.8% (21.5) | | 0.5% (3.4) | **0%** |
| No | All verbs | 337/960 | | 59/623 | **−11** | 3/337 | |
| | | 35.1% (38.7) | | 9.4% (21.7) | **−0.4%** | 0.5% (3.9) | |
| Yes | Copula verb | 187/479 | | 30/292 | | 1/187 | **−1** |
| | | 39.0% (38.2) | | 9.2% (21.1) | | 0.4% (3.2) | **−0.3%** |
| | Thematic verb | 156/479 | | 40/323 | | 2/156 | **1** |
| | | 32.5% (36.9) | | 10.3% (21.7) | | 0.7% (3.7) | **0.5%** |
| No | Copula verb | 166/480 | | 29/314 | | 2/166 | |
| | | 34.6% (39.2) | | 9.1% (21.8) | | 0.7% (5.1) | |
| | Thematic verb | 171/480 | | 30/309 | | 1/171 | |
| | | 35.6% (38.0) | | 9.7% (21.4) | | 0.2% (1.8) | |

**Table 8.** Study 2: Models for priming task (*n* = 60).

| Variable | | Estimate | SE | t | p |
|---|---|---|---|---|---|
| Adverbial Fronting | Intercept | −1.767 | 0.478 | −3.700 | <.001 |
| | Prime Type | −0.163 | 0.102 | −1.592 | .111 |
| | Proficiency | 0.055 | 0.467 | 0.119 | .906 |
| | Prime Type*Proficiency | −0.083 | 0.083 | −0.995 | .320 |
| | Formula: ADV-Fronting ~ 1 + Prime Type + scale(LexTale.Score) + Prime Type:scale(LexTale.Score) + (1 + Prime Type | Subject) + (1 + scale(LexTale.Score) | Item) | | | | |
| TP-LP orders | Intercept | −4.109 | 0.531 | −7.746 | <.001 |
| | Prime Type | −0.066 | 0.318 | −0.209 | .835 |
| | **Proficiency** | **−1.684** | **0.509** | **−3.311** | **<.001** |
| | Prime Type*Proficiency | 0.004 | 0.268 | 0.135 | .893 |
| | Formula: TP-LP ~ 1 + scale(LexTale.Score) + Prime Type + scale(LexTale.Score):Prime Type + (1 + Prime Type | Subject) + (1 + scale(LexTale.Score) | Item) | | | | |

*buildmer* function are given in Table 9. Since there were no V2 productions in the posttest at all, we did not run a model for verb second due to convergence issues.

For fronted adverbials, learners produced more fronted utterances in the posttest (483/1434; *M* = 32.8%; *SD* = 40) than at baseline (367/1413; *M* = 26.0%; *SD* = 23; mean difference = 6.8%; see also Figure 3). For TP-LP orders, overall, their proportion decreased in the posttest (65/951; *M* = 7.3%; *SD* = 17%) compared to baseline (147/1046; *M* = 16.3%; *SD* = 26; mean difference = −9.0%). The interaction of task and proficiency indicates that lower-proficiency learners reduced the number of dispreferred TP-LP orders they produced from baseline to posttest, while the proportion of TP-LP orders remained at low levels for more highly proficient speakers across both. Sentences with ungrammatical V2 dropped to zero in the posttest compared to thirteen instances of ungrammatical V2 sentences with copula verbs and two with thematic verbs at baseline. Finally, for verb raising, despite a numerical reduction of sentences with postverbal medial adverbs from baseline (48/717; *M* = 6.7%; *SD* = 14) to posttest (17/720; *M* = 2.4%; *SD* = 6.7; mean difference = −4.3%), there was no effect of task; instead, proficiency modulated the proportion of ungrammatical sentences across baseline and posttest.

## Discussion

In the priming task, the more advanced learner group in Study 2 demonstrated significant priming of the fronting of adverbials for copula verbs, yet not for thematic verbs. In view of the fact that we did not observe such a contrast according to verb type in Study 1 and that fronting is not constrained according to verb type in German, it is not obvious why the priming effect only reached significance for one verb type. Given that there is no partial word order overlap for fronting with

**Table 9.** Study 2: Models for Baseline vs Posttest ($n = 60$).

| Variable | | Estimate | SE | t | p |
|---|---|---|---|---|---|
| Adverbial Fronting | Intercept | −3.586 | 0.549 | −6.568 | <.001 |
| | **Task** | **−0.287** | **0.054** | **−5.291** | **<.001** |
| | Proficiency | −0.147 | 0.350 | −0.420 | .674 |
| | Task*Proficiency | −0.026 | 0.056 | −0476 | .634 |
| | Formula: ADV-Fronting ∼ 1 + Task + scale(LexTale.Score) + Task: scale(LexTale.Score) + (1 | Subject) + (1 | Item) | | | | |
| TP-LP orders | Intercept | −3.705 | 0.357 | −10.369 | <.001 |
| | **Task** | **0.875** | **0.160** | **5.468** | **<.001** |
| | **Proficiency** | **−1.419** | **0.358** | **−3.959** | **<.001** |
| | **Task*Proficiency** | **0.515** | **0.199** | **2.593** | **.009** |
| | Formula: TP-LP ∼ 1 + Task + scale(LexTale.Score) + Task: scale(LexTale.Score) + (1 | Subject) + (1 + scale(LexTale.Score) | Item) | | | | |
| Verb raising | Intercept | −5.094 | 0.575 | −8.858 | <.001 |
| | Task | 0.488 | 0.524 | 0.931 | .352 |
| | **Proficiency** | **−1.656** | **0.512** | **−3.236** | **.001** |
| | Task*Proficiency | −0.210 | 0.437 | −0.481 | .631 |
| | Formula: Verb Raising ∼ 1 + scale(LexTale.Score) + Task + scale(LexTale.Score):Task + (1 + Task | Subject) + (1 | Item) | | | | |

thematic verbs, the L2 learners may inhibit fronting with thematic verbs more in general[4]. In the comparison of posttest to baseline, the adult group of learners showed significant longer-term priming for fronted adverbials across both verb types.

As for CLI with dispreferred and ungrammatical structures, the group of more advanced learners in Study 2 produced dispreferred TP-LP and ungrammatical V2 word orders at relatively lower levels at baseline overall compared to the less-proficient learners in Study 1. Though at low levels overall, the learners supplied more ungrammatical V2 for copula than for thematic verbs, bearing out that CLI continues to be higher for structures with partial word order overlap. In the priming task, there was no change for dispreferred TP-LP orders depending on whether the prime sentences had the same surface word order – however, the learners produced fewer TP-LP orders in the priming task (9.6%) than at baseline (14.6%). The learners produced almost no instances of ungrammatical V2 in the priming task, so that we could not observe any effects of cross-linguistic priming for ungrammatical structures. For longer-term priming, the learners supplied significantly fewer dispreferred and ungrammatical word orders in the posttest than at baseline. Ungrammatical V2 orders reduced to zero, even though the overall number of sentences with fronted adverbials that would permit the use of verb second actually increased in the posttest. Again, for structures with verb raising that were

not used in the L1 during the priming phase, there was no change in production frequency. Effects of proficiency emerged for the overall production of sentences with TP-LP adverbial ordering across all tasks and for sentences with ungrammatical verb raising in baseline and posttest. These effects reflected a lower proportion of L1-based word orders among more highly proficient L2 learners. We did not find any interactions of proficiency with priming.

In sum, Study 2 with more advanced learners replicates the asymmetrical priming pattern of Study 1, but with fewer dispreferred TP-LP, ungrammatical V2, and verb raising utterances overall. In addition, the more proficient L2 learners also demonstrated longer-term priming of optional adverbial fronting.

## General discussion

In two studies, we examined proposals that cross-linguistic structural priming is a mechanism of cross-linguistic influence by testing whether priming systematically increases CLI in bilingual language production and whether it is modulated by the same factors as CLI. We applied two proposals originally raised in the context of child bilingual learners to early and adult sequential L2 learners who exhibit greater CLI than child simultaneous bilinguals. On the one hand, we found clear evidence of cross-linguistic structural priming for grammatical optional word orders in German and English. On the other hand, in neither Study 1 nor Study 2 did we find any evidence that cross-linguistic priming systematically enhanced CLI of dispreferred or ungrammatical L1-based word orders in the L2. Even though the low-proficiency learners in Study 1, in particular, supplied substantial numbers of CLI in terms of L1-based word orders in their L2 English at baseline, the subsequent use of these word orders in German primes did not boost the proportion of their occurrences in English. On the contrary, the proportions of dispreferred and ungrammatical word orders produced in the L2 were lower both during and after the priming task than at baseline. These decreases in production only affected structures that were contained in the priming phase, but did not generalize to other ungrammatical L1-based word orders, such as verb raising. In the following, we discuss these findings in relation to our research questions.

As for our general research question (GQ), the findings suggest that, as in previous studies, cross-linguistic structural priming boosts CLI in terms of the production of related and grammatical options across languages. For adverbial fronting, the lower-proficiency L2 learners in Study 1 exhibited short-term priming, and the more highly proficient L2 learners in Study 2 also demonstrated and longer-term priming. At low proficiency, learners may rely on explicit memory strategies in encoding the format of the prime sentences in short-term memory (e.g., Ferreira & Bock, 2006; Hartsuiker & Bernolet, 2017; Pickering & Ferreira, 2008), from which they are retrieved as templates for the following target trial. Such explicit strategies may lead to cumulative priming in the course of an experiment as users keep reusing the same structure (as observed in Study 1), yet they commonly do not translate into longer-term priming across tasks, since the activation of the structures committed to memory fades across trials and is unlikely to persist across tasks into later production. In more advanced L2 learners, the effects of priming are more abstract and persist longer (see also Hwang & Shin, 2019).[5]

In terms of the two approaches to priming as a mechanism that underlies CLI examined in this paper, the studies did not yield the full priming patterns predicted by either model. However, the findings that effects of priming on CLI can be both long-term and that they are specific to the grammatical structures activated in the task provide some evidence against the proposal that priming enhances CLI by virtue of the global short-term activation of the L1 (Serratrice, 2016). Rather, it appears to lead to the increase in the activation of specific grammatical options whose production frequencies may be cumulatively affected well beyond the priming phase. In this regard, the findings are more compatible with the idea that CLI is the consequence of cross-linguistic activation of shared or related grammatical nodes under lexical overlap (Nicoladis, 2006). According to this account, priming non-selectively activates (sub-)lexical and grammatical information associated with these nodes across languages in the bilingual lexicon. Each activation boosts the resting activation level of the grammatical structure selected, so that its likelihood of getting selected again increases incrementally. Conversely, it stands to reason that priming will not affect grammatical nodes the speaker does *not* activate in language use. Since verb raising across adverbs did not occur in the priming task, its activation levels did not change, and, as a result, we see comparable levels of ungrammatical uses of verb-adverb orders in the baseline and the posttest.

As for the specific research question about whether key features of CLI also modulate priming, RQ1 asked whether the well-formedness of the structure affects cross-linguistic priming. In both Study 1 and Study 2, although learners produced CLI for these structures at baseline, there was no evidence of short-term or long-term priming of dispreferred or ungrammatical structures in the L2 boosting CLI. Instead, the current study found "anti-priming" in that the frequency of L1-based word orders that are dispreferred or ungrammatical word orders in the L2 decreased from baseline via the priming task to the posttest. These results clearly refute the general hypothesis that priming generally *enhances* CLI across grammatical, dispreferred, and ungrammatical structures. Instead, these findings suggest that the cross-linguistic activation of the competing L1 structure in the priming task propels learners to "zoom in" (Elston-Güttler et al., 2005) on the L2 and inhibits incongruent L1 word orders. The resulting greater convergence on licit grammatical structures in the L2 is all the more noteworthy since the participants at no point received any L2 input in the study or any feedback on the accuracy of their L2 utterances.

These anti-priming effects found for dispreferred and ungrammatical structures are broadly similar to "overcorrection" observed as a strategy among (adult) bilinguals to differentiate multiple languages in their repertoire according to their grammatical properties (Kupisch, 2014). In (unprimed) production, adult bilinguals tend to underuse cross-linguistically overlapping structures and produce more language-particular structures compared to monolingual speakers (see also Kupisch & Barton, 2013). Observing similar differentiation in adult heritage speakers, Anderssen et al. (2018) propose that "cross-linguistic overcorrection" (CLO) to separate grammars in use is the consequence of speakers' "overinhibition" of similar structures from the other language, which, in turn, leads to the over-activation of structures that are distinct between languages, especially among more highly proficient speakers of the L2.

Critically, these asymmetrical cross-linguistic priming effects found for grammatical versus dispreferred and ungrammatical structures in the L2 suggest that priming effects resulting from cross-linguistic activation of the L1 interact with knowledge of the L2 grammar. For grammatical structures, cross-linguistic structural priming increases the activation of the licit option of adverbial fronting in the L2. For dispreferred and ungrammatical structures, it leads to learners inhibiting CLI in terms of L1-based structures. The involvement of L2 grammatical knowledge becomes particularly clear in the following two instances. First, within sentences with fronted adverbials, L2 learners produced more fronted adverbials following the German prime structure, while at the same produced fewer instances of another feature of this very structure, namely the V2 word order. Second, the L2 learners in Study 1 produced optional adverbial fronting to the same degree as dispreferred TP-LP orders at baseline (Figure 2). Subsequently, their use of adverbial fronting increased in the priming task, while the levels of use of TP-LP orders decreased, even though both structures were presented at the same frequency in the L1 primes. Hence, the interlanguage grammar appears to impose asymmetrical effects on L1 activation. Even when learners produce substantial CLI in the form of ungrammatical L2 word order based on the L1 (Study 1), the subsequent activation of the L1 in L2 production is gated by the interlanguage grammar.

In RQs 2 and 3, we addressed modulating language and learner factors of CLI. RQ2 addresses the role of partial word order overlap by testing for an interaction of priming with verb type in the production of ungrammatical verb second. Partial word overlap affected CLI in both studies, as seen in the higher production of verb second with copula compared to thematic verbs at baseline. However, it did not in turn lead to greater cross-linguistic priming of verb second in either study.

In RQ3, we asked how proficiency would affect cross-linguistic structural priming. In Study 2, we found that proficiency modulates the overall proportions of ungrammatical and dispreferred L1-based word orders in the L2 at baseline and posttest. However, there was no systematic interaction of priming and proficiency across structures. When descriptively comparing the low-proficiency L2 learners in Study 1 with the more highly proficient learners in Study 2, the main difference lies in the absence of long-term priming of adverbial fronting in Study 1. However, for CLI with dispreferred and ungrammatical L2 word orders, there were similar patterns between Study 1 and 2 in how their levels of use changed as a result of priming. These findings suggest that proficiency predominantly affects the baseline levels of CLI; yet, it does not modulate the degree of cross-linguistic priming. Even the low-proficiency learners in Study 1 appeared to use their emergent and unstable L2 grammatical knowledge to differentiate between cross-linguistically shared and cross-linguistically distinct grammatical structures.

In all, the present studies indicate that the role of cross-linguistic priming as a mechanism of CLI is narrowly circumscribed to boosting the production of grammatical structures that are shared across languages; in contrast, cross-linguistic structural priming does not enhance the production of dispreferred or ungrammatical L1-based word orders in the L2, and – unlike CLI – it is not modulated by word order overlap or L2 proficiency for these structures.

These findings also have implications for the developmental models of L2 production formulated on the basis of cross-linguistic priming data, such as the Shared

Syntax Model (Hartsuiker & Bernolet, 2017). According to this model, CLI may surface in beginning learners who have no L2-specific representations available yet and thus lean on the L1 grammar, as well as in advanced learners who may over-extend syntactic sharing between L1 and L2 to language-specific features of a shared structure, for example, V2 as a property of fronting (Bernolet & Hartsuiker, 2018, 218–219). To the extent that the learners in our Study 1 and 2 represent beginning and advanced learners, respectively, the finding that both groups demonstrate CLI at baseline is compatible with the Shared Syntax Model, as is the overall lower amount of CLI in the more advanced vs the beginning learners. Crucially, however, the model would also predict there to be cross-linguistic priming of dispreferred and ungrammatical structures when they are attested in L2 production. It thus remains to be seen how the asymmetrical effects of cross-linguistic priming we observed in this paper can be accommodated in models of L2 production formulated in terms of transfer and sharing, such as the Shared Syntax Model.

Needless to say, the conclusions of the present study are constrained by its limitations. We could not make any direct statistical comparisons between Study 1 and Study 2, since the learners not only differed in proficiency but also in age, as we wanted to follow their developmental trajectory of learning. Future studies could also investigate effects of L2 experience for age-matched learners. Further, since we tested foreign-language learners who learn the L2 in an instructed setting, they may in part lean on knowledge of explicit rules regarding English word order when they prepare ordering the sentence fragments in the task. To address this issue, it would be interesting to run this study with L2 learners who acquired the L2 in naturalistic settings or even younger learners who have less explicit knowledge of the target. Similarly, it would be interesting to impose a tighter time limit on the participants in producing their utterances to restrict the time available to recruit explicit knowledge. However, many participants struggled to form sentences within the ten seconds the fragments were displayed in Study 1, so that further cutting the time available for their response will lead to missing data.

In addition, future studies should investigate cross-linguistic effects on ill-formed grammatical structures beyond combinations of prime and target sentences that share the same verbs. Extending the scope of priming can address the question of whether the inhibition effects we found are circumscribed to co-activation of lemma entries, that is, lexical nodes of individual verbs, or whether they generalize to grammatical structures independently of the lexical items embedded therein. Moreover, studies should systematically vary the number and types of (un-)grammatical structures in the experiment. In our studies, participants may have become aware that some of the structures they encountered are licit in both the L1 and the L2 and some others are specific to either. They may have benefitted from the realization of these contrasts in tailoring their production to the L2. In our study, the present findings are limited to production priming, and it would be interesting to study the relative activation of (un)grammatical options and the time course of priming effects in sentence comprehension (e.g., Hopp & Grüter, 2021). Finally, future research could study other or additional mechanisms potentially engendering grammatical CLI on top of cross-linguistic priming, for example, the use of cognates that occasion lexical co-activation of the L1 (e.g., Hopp, 2017; Hopp & Lemmerth, 2018), temporal or cognitive constraints that may prompt L2 learners to make

recourse to more stable and more accessible L1 structures in real-time production (e.g., Jackson et al., 2017).

In sum, the present study finds that cross-linguistic structural priming has asymmetrical effects on CLI with well-formed and ill-formed grammatical structures in the L2. Not least, these findings have applied implications for the foreign-language (FL) classroom and the use of the L1 in FL teaching. Previous studies reported that explicit instruction about cross-linguistic differences between the L2 and the L1(s) can benefit FL learning (e.g., Hopp & Thoma, 2021) or FL processing (e.g., McManus & Marsden, 2019). The present study adds that the contrastive use of the L1 may aid FL learners to "zoom in" on the L2 grammar even in the absence of explicit instruction. In this respect, the study adds a novel dimension to the potential uses of priming in FL instruction (for review, McDonough & Trofimovich, 2011). Particularly in light of these implications, further research on effects of cross-linguistic priming on CLI and L2 learning is called for.

## Notes

**1.** An anonymous reviewer asks what the appropriate alpha-level adjustments would be on the assumption that the study tests the general research question "Is there priming?" across several structures and studies. However, the study tests different research questions. In relation to RQ1, the hypothesis this study explores is whether priming extends *across* different structures, i.e. well-formed, dispreferred, and ungrammatical structures. In other words, there should be priming in each structure. This corresponds to the case of "individual testing" (Rubin, 2021), in which each individual result must be significant in order to reject each associated individual null hypothesis, namely that there is no priming in that specific structure. As is clear, these are individual null hypotheses, since "a single test result is used to make a decision about a single null hypothesis, then that test result provides only one opportunity to make a Type I error about that null hypothesis. Consequently, the alpha level of the test ($\alpha$ - Individual) does not need to be lowered." (Rubin, 2021, 10978). As regards effects of Verb Type in RQ2, we test the individual hypothesis that Verb Type modulates the use of V2 in one structure, namely verb second. RQ2 tests a different hypothesis compared to RQ1, and the interaction of Verb Type and Task is used to interpret effects of word order overlap on priming for sentences with V2 only. Finally, as for proficiency, RQ 3 and its associated hypothesis predict an interaction of priming with proficiency, and the results are interpreted relative to this hypothesis. However, one could argue that the priming task and the baseline-to-posttest task each test a more general question of "Is there priming?" in each structure. When interpreting the results in the context of this research question, the alpha level should be corrected to $p = .025$ in each study.

**2.** We also ran models that included the CLT score as a centered and scaled variable. Neither in the priming task nor in the comparison of baseline and posttest did the inclusion of proficiency lead to qualitatively different patterns of findings.

**3.** We could not use the same proficiency task as in Study 1, since all learners in Study 2 would likely have performed at ceiling in the CLT, a picture-naming task of high-frequency words. Conversely, the LexTALE is too difficult for learners at low proficiency levels as in Experiment 1, and it would have led to large-scale guessing. Therefore, we decided to use proficiency tests that were appropriate to each population.

**4.** We thank an anonymous reviewer for suggesting this potential explanation.

**5.** Anonymous reviewers pointed out that differences in the findings between Studies 1 and 2 may also be due to variation in the participants' ages at testing, since priming in children may differ from priming in adults. While we acknowledge that this may be an alternative option, previous findings that low-proficiency adult learners also predominantly show short-term priming only (e.g. Jackson & Ruf, 2017) and children also show long-term priming (e.g. Kidd, 2012) suggest that age differences, in the absence of proficiency differences, may not easily account for the different findings between Studies 1 and 2.

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