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RESEARCH ARTICLE

Processing to learn noncanonical word orders: Exploring linguistic and cognitive predictors of reanalysis in early L2 sentence comprehension

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Abstract

To test the contributions of processing to L2 syntax learning, this study explores (cross-) linguistic and cognitive predictors of sentence reanalysis in the L2 comprehension of relative clauses among low-intermediate L1 German adolescent learners of L2 English. Specifically, we test the degree to which L2 comprehension is affected by L2 proficiency, reanalysis ability in a related, earlier-acquired L2 structure (questions), reanalysis ability of relative clauses in the L1, cognitive control, and cognitive capacity. In visual-world eye-tracking experiments, 141 adolescent German-speaking L2 learners of English selected target pictures for auditorily presented questions and relative clauses in the L1 and in the L2. The results showed a strong subject preference for L2 relative clauses. Learners' L2 proficiency and their processing of object questions in the L2 predicted reanalysis for object relatives in eye movements, reaction times, and comprehension accuracy. In contrast, there was no evidence that cognitive control or working memory systematically affected the processing of object relatives. These findings suggest that linguistic processing outweighs cognitive processing in accounting for individual differences in low-intermediate L2 acquisition of complex grammar. Specifically, learners recruit shared processing mechanisms and routines across grammatical structures to pave a way in the acquisition of syntax.

Introduction

A central puzzle in research on first or second language acquisition is how we can learn something that we do not already know how to process. Take the passive structure: "John is kissed by Mary." Before learners have command of this grammatical structure, studies show that they only have the (active) interpretation "John kisses Mary" available (e.g., Abbot-Smith et al., 2017). For them to acquire the grammatical structure of passives means that they (a) need to realize that the string "John is kissed by Mary" cannot be parsed as the active structure with the agent as the first noun, (b) have sufficient processing resources to inhibit and revise the agent-first interpretation to interpret the sentence as a patient-first string, and (c) thereby acquire the corresponding grammatical structure of a passive. As a consequence, language processing must be a key component in acquisition in that learners engage in *processing to learn* (Fodor, 1998; Omaki & Lidz, 2015; Phillips & Ehrenhofer, 2015). Psycholinguistic approaches to language acquisition couched in different frameworks converge in assuming that language processing and its components, such as predictive processing (Huettig, 2015; Pickering & Garrod, 2013), priming (Chang et al., 2006), and processing efficiency (Hurtado et al., 2014), contribute to language learning in that they allow learners to extract information from the input as well as to overcome learning biases.

In turn, the late acquisition of complex grammar, such as passives or object relative clauses (Bencini & Valian, 2008; Borer & Wexler, 1987; Messenger et al., 2011), has been related to the developing sentence processing mechanisms that, for example, curtail the successful revision of canonical agent-first clauses to passives or object-first relative clauses in children (Abbott-Smith et al., 2017; Huang et al., 2013). One reason for the late acquisition of complex grammar may be that sentence revision hinges on the employment of a cognitive control mechanism that is responsible for inhibiting the analysis initially adopted (Mazuka et al., 2009; Novick et al., 2010; Thothathiri et al., 2018) and that reanalysis taxes working memory resources (Boyle et al., 2013; for a review, see Kidd, 2013). The development of these cognitive mechanisms themselves takes time (Davidson et al., 2006) so that domain-general cognitive processing may be a primary cause in delaying grammatical development (Kidd et al., 2011; Mazuka et al., 2009; Qi et al., 2020; Trueswell et al., 1999; Woodard et al., 2016).

In this study, we assess the relative contributions of cognitive and language processing to learning among early second language learners. Studying beginning L2 learners affords additional insights into relations between processing and learning, as sequential L2 learners are older and thus cognitively more mature than child L1 learners. As a result, grammatical L2 development and the development of working memory or cognitive control in a given individual are not necessarily correlated such that they can be empirically dissociated. For adult L1 speakers and adult L2 speakers with high command of the L2, working memory and cognitive control have been shown to be implicated in the successful comprehension of complex sentences (for L1, see Hsu et al., 2021; for L2, see Navarro-Torres et al., 2019; Pozzan et al., 2014; Teubner-Rhodes et al., 2016). However, to our knowledge, no study has directly tested their roles in L2 processing among less proficient L2 learners who are in the process of acquiring complex sentences. In the present study, one question we explore is how working memory and inhibitory control modulate the processing and learning of complex syntax among low-proficiency L2 learners.

Moreover, L2 learners—unlike L1 learners—can lean on knowledge and the processing of a previously acquired L1 and thus potentially transfer processing routines from the L1 to facilitate L2 sentence comprehension. There is both indirect and direct evidence of such cross-language facilitation. Research on L2 reading provides indirect evidence of across-language links in that L1 reading affects L2 reading skills, encompassing accurate sentence comprehension (e.g., Sparks et al., 2009, 2019; see also Kuperman et al., 2023). Research on cross-linguistic structural priming provides direct evidence of L1–L2 links. Structural priming refers to speakers' tendencies to reuse grammatical structures after recently having encountered them in the input (Bock, 1986). In cross-linguistic structural priming studies, bilingual children as well as L2 learners adapt their sentence production or comprehension in one language to the prime structures that they are exposed to in a different language (for bilingual children, Vasilyeva et al., 2010; for adults, see review in Van Gompel & Arai, 2018). Similarly, priming experiments conducted within the L2 show that structural priming can facilitate the production and comprehension of complex syntax (e.g., Fujita & Cunnings, 2021; Jackson & Hopp, 2020; Kidd, Tennant & Nitschke, 2015; for a review, Jackson, 2018). Such evidence of across- and within-language structural priming suggests that the prior processing of a grammatical structure can facilitate the production and comprehension of a subsequent similar structure. In this study, we probe whether immediate and short-term facilitatory effects previously found in priming tasks generalize to regular L2 comprehension by virtue of the activation of shared processing mechanisms across different grammatical structures that require reanalysis. Specifically, we test whether learners' abilities in processing comparable grammatical structures in the L1 and the L2 that have been acquired earlier or to larger degrees boost the processing and acquisition of an emergent L2 structure.

In this exploratory study, we investigate the comprehension of relative clauses among lower proficiency adolescent L2 learners who are in early stages of L2 acquisition. We seek to identify cognitive and (cross-)linguistic predictors in the comprehension of relative clauses in order to assess the degree to which (a) cognitive processing and (b) linguistic processing within the L2 and in the L1 facilitate sentence comprehension and thus pave a way to the acquisition of noncanonical word orders.

The acquisition and processing of noncanonical orders: Questions and relative clauses

Noncanonical word orders represent word orders that deviate from the unmarked or basic word order of a language, for example, SVO in English. For grammatical structures such as questions (1) and relative clauses (2), they arise as the result of reordering due to syntactic movement and mark interpretive differences through word order changes.

(1) a. Which animal$_{\mathrm{SUBJ}}$ t chases the mouse$_{\mathrm{OBJ}}$?
    b. Which animal$_{\mathrm{OBJ}}$ does the mouse$_{\mathrm{SUBJ}}$ chase t?

(2) a. Where is the animal that$_{\mathrm{SUBJ}}$ t chases the mouse$_{\mathrm{OBJ}}$?
    b. Where is the animal that$_{\mathrm{OBJ}}$ the mouse$_{\mathrm{SUBJ}}$ chases t?

According to transformational theories of syntax (Chomsky, 1986), the differences in word order in (1 & 2) follow from displacement of the subject or object wh-phrase from the canonical position in which it is interpreted (represented by a trace, t) to the clause-initial position that signals the type of structure—that is, a wh-question in (1) or a relative clause in (2). As seen in (1 & 2b), object questions and object relative clauses are characterized by the object wh-phrase or complementizer preceding the subject. In this respect, these orders are noncanonical, as the object, which encodes the semantic role of patient, precedes the subject encoding agents. Across languages, monolingual children acquire canonical subject questions and subject relative clauses before object questions and object relative clauses and perform better in the comprehension of subject than object orders (for questions, see De Vincenzi et al., 1999; Guasti et al., 2012; for relative clauses, see Adani, 2011; Adani et al., 2010; Durrleman et al., 2016; Friedmann & Novogrodsky, 2004; Lau & Tanaka, 2021). Such differences in the acquisition between subject and object orders have been argued to follow from subject-first orders being the canonical order in that the thematic role assignment of agent and patient is linearly

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mapped onto argument order (canonicity hypothesis; Friedmann & Novogrodsky, 2004).

In both L1 production and comprehension, target subject questions emerge between age 2 and 3, whereas, for instance, English-speaking children do not reach mastery of object orders until age 4 to 5 (Correa, 1995; De Villiers et al., 1979). For object relative clauses, convergence on target accuracy occurs even later around age 6, and younger children also perform better on object questions than object relatives (Durrleman et al., 2016). In early L2 acquisition, child and adult learners also acquire questions before relative clauses and show more accurate comprehension of the former than the latter (e.g., Hopp et al., 2019). Furthermore, (instructed) learning of object questions does not generalize to object relatives (Hopp & Thoma, 2021). Taken together, these asymmetries suggest that the acquisition of these different noncanonical orders operates on different timescales and levels of generalization.

However, according to many approaches, object questions and object relative clauses are closely linked at the level of sentence processing in that they both require the parser to revise its initial subject interpretation to an object order (e.g., De Vincenzi, 1991). Within serial approaches to sentence processing, the subject/agent-first preference has been conceptualized as the consequence of an active filler strategy, according to which comprehenders strive to fill a gap in the processing of syntactic dependencies as soon as possible once they encounter a filler—for example, a wh- or a relative pronoun (Frazier, 1987). When listeners then encounter lexical items incompatible with a subject-first interpretation—namely, the auxiliary *does* in object questions (1b), or a filled gap—that is, the subject NP in object relatives (2b)—they need to revise their initial analysis and reanalyze the partial representation of the incoming sentence toward an object question or relative clause. In other words, the parser needs to perform reanalysis. Such reanalysis has been described as the partial reprocessing of the input string or a reassignment of grammatical functions in garden-path models of sentence processing (Fodor & Inoue, 2000; Frazier, 1987). Within constraint-based models of sentence processing (McRae & Mazuki, 2013), reanalysis implicates the inhibition of the erroneous parse and a greater activation of the erstwhile latent object parse. On the assumption that reanalysis involves similar processing mechanisms for object questions and relative clauses, language processing experience with reanalyzing subject to object-first questions could hone the comprehension of object relative clauses.

Importantly, reanalysis also implicates cognitive processing, in particular working memory and cognitive control. According to serial processing models, object-first orders tax working memory because they require comprehenders to store a filler in working memory across a longer dependency than with subject-initial orders (Gibson, 1998), and the intervening subject may interfere during the retrieval of the filler from working memory at the gap site (Lewis & Vasishth, 2006). Within constraint-based models of sentence processing, working memory restricts the number of alternative analyses a comprehender can compute and store in memory simultaneously (Just & Carpenter, 1992). In line with these accounts, previous research has found effects of working memory in the processing and comprehension of (object) relative clauses, with high-span readers being able to resolve ambiguous relative clauses or comprehend object relatives better than low-span readers (for L1, see Arosio et al., 2012; Swets et al., 2007; for L2, see Cheng et al., 2021; Hopp, 2014). Furthermore, the efficiency of inhibitory control mechanisms as part of executive function affects the ease with which comprehenders can inhibit the activation of the prepotent analysis and, in turn, raise activation of alternatives consistent with noncanonical word orders that the user then selects as the ultimate parse. For instance, several studies on the processing of temporarily ambiguous sentences report effects of cognitive control on the speed and the success of ambiguity resolution in garden-path sentences (Hussey et al., 2017) as well as noncanonical word orders, for example, passives (Thothathiri et al., 2018). Recent neurophysiological studies further support this link between sentence revision during language processing and cognitive control (for a review, Sharer & Thothathiri, 2020). In summary, then, various dimensions of cognitive and linguistic processing are jointly implicated in the comprehension of noncanonical word orders and thus may contribute to the acquisition of complex grammar.

Research questions and hypotheses

In this study, we explore the comprehension of noncanonical word orders in low-proficiency L2 learners who are beginning to acquire these noncanonical orders in the L2. We test which factors modulate the processing of developing structures in an L2 on the assumption that the more often a developing L2 structure is successfully processed, the more stable and accessible its resulting grammatical representation will become. In this way, successfully reanalyzing sentences to the noncanonical order will ultimately facilitate L2 acquisition of the noncanonical grammatical structure. We next detail how different aspects of (cross-)linguistic and cognitive processing may affect successful processing.

In terms of *linguistic processing*, target comprehension of a less challenging and earlier-acquired grammatical structure could affect the comprehension of a more challenging grammatical structure, because both structures may implicate analogous revision mechanisms in language processing. Specifically, L2 learners could apply reanalysis from questions to other grammatical structures involving reanalysis, for example, relative clauses. For these possible *intra-L2 processing relations*, we assess the degree to which the processing of object questions correlates with the processing of L2 object-initial relative clauses. Sequential (L1-dominant) L2 learners can perform reanalysis with less effort and greater success in the L1 than the L2. On the assumption that sentence revision processes scope across languages (Beatty-Martinéz & Dussias, 2018), a learner's ability to complete reanalysis in the L2 may in part depend on their ability to do so in the more dominant language. For such potential *inter-language processing relations*, we investigate whether the aptitude of processing object relative clauses in German affects reanalysis with object relative clauses in English among adolescent L2 learners.

In terms of *cognitive processing*, the working memory capacity and executive function of an individual have been shown to influence the degree to which the individual can successfully complete reanalysis (e.g., Hussey et al., 2017). In order to test the degree to which reanalysis skills in an emergent L2 depend on cognitive factors providing learners with the requisite resources to perform sentence revision, we assess effects of *cognitive capacity*—that is, working memory—on the processing of noncanonical orders. Furthermore, based on initial findings for L1 children that *cognitive control* affects reanalysis by inhibiting a prepotent canonical order (Thothathiri et al., 2018), we test how a learner's *cognitive control* modulates reanalysis with noncanonical word orders.

In view of these possible relations, we ask the following exploratory research questions:

1) How is the processing of a more challenging noncanonical order in the L2—that is, object relative clauses—related to the processing of a less challenging structure in

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the L2 that also implicates reanalysis—that is, object questions? (*linguistic processing relations within L2*)
2) How is the processing of noncanonical orders in the L2 aided by processing facility of this order in the L1? Specifically, does greater ease in processing object relatives in the L1 (German) lead to facilitation in the processing of English object relative clauses? (*linguistic processing relations between L2 and L1*)
3) How is the processing of noncanonical orders in the L2 dependent on working memory resources and inhibitory control? (*cognitive-to-linguistic processing relations*)

We address these questions in an experiment that also controls for other factors known to affect (L2) processing of noncanonical word orders, in particular proficiency in the L2. We administered two visual-world eye-tracking experiments to investigate early and later stages of auditory sentence processing and comprehension. We analyze the relative looks to scenes corresponding to the interpretation of canonical and noncanonical word orders, respectively, during sentence processing as a measure of how quickly comprehenders can initiate reanalysis. Second, we analyze reaction times of selecting the appropriate scene as a measure of how fast participants complete reanalysis. Finally, we analyze comprehension accuracy as a measure of how successfully participants complete reanalysis. This last measure can also be seen as an index of successful acquisition, since it encompasses both target processing and interpretation.

Method

Participants

A total of 141 adolescent L1-German learners of L2 English took part in the study. They were recruited from grades 7–8 of German high schools in the cities of Braunschweig and Dortmund. The students had a wide range of background in terms of socioeconomic background, as measured in a 5-point rank scale for their parents' highest level of education: 1 = no school-leaving qualification ($n = 4$), 2 = secondary school diploma ($n = 4$), 3 = high school diploma ($n = 32$), 4 = university degree ($n = 69$), 5 = doctoral degree ($n = 20$); NA: $n = 12$). All participants had started learning English as a foreign language at elementary school level between the ages of 6 and 8 years. They participated voluntarily and received a compensation of 25 Euros for their participation. Sixteen participants were excluded from further analyses due to missing data, and 11 participants were excluded because of additional exposure to English at home, leaving 114 participants for analysis. These participants (64 female, 50 male) were all learners of L2 English; 34 of them were raised bilingually with a language other than German or English. For proficiency in German and English, participants completed a semantic fluency task in both languages in which they named as many exemplars as possible within 60 s for the categories "sports" and "things you can find in the kitchen" for German and "food" and "things you can find in the classroom" for English (Bialystok et al., 2008; between-category reliability for sample: $r = .480$ in English and $r = .431$ in German) as well as the 32-item noun-production part of the Cross Linguistic Lexical Task (CLT; Haman et al., 2015; split-half reliability for the sample: $r = .70$). Both parents and their children completed a background questionnaire based on the Language and Social Background Questionnaire (LSBQ; Anderson et al., 2018). Participant information is summarized in Table 1. Ethical approval was granted by the Ethics Committee of the German Linguistic Society (*DGfS*, ethics vote no. 2020-20-210204), and the study

Table 1. Participant characteristics (*n* = 114)

	M	(*SD*)	Range
Age (years)	13.0	(0.6)	11.9–14.9
Semantic fluency German[a]	33.0	(8.0)	17.0–55.0
Semantic fluency English[a]	24.0	(6.0)	10.0–42.0
CLT score[b]	18.9	(3.6)	12.0–28.0

[a]Raw scores collapsed across two semantic categories per language.
[b]Raw score with a maximum of 32 possible.

was approved by the regional school board and followed the Helsinki convention. Informed consent was secured from both children and their parents.

Materials

In two visual-world eye-tracking experiments, participants heard a question in either German (Experiment 1) or English (Experiment 2) while looking at two pictures in one display (Figure 1).

In total, 360 target sentences were created based on the names of 20 easily identifiable animals engaging in 10 different actions, expressed by verbs. Sentences were either in German (3–6a) or in English (3–6b) and were subject (3) or object (4) wh-questions or subject (5) or object (6) relative clauses in simple present tense.[1] The English and German sentences were created such that they made reference to the same two animals and the same action, but which animal name was mentioned in the sentence was reversed between languages. Additionally, participants were presented with subject and object wh-questions containing an inanimate question word (*what/was*) instead of *which animal/welches Tier*, as in (3–4), for example, *What does the penguin hug?* However, this condition will not be further examined in this paper.

(3) a. Welches Tier umarmt den$_{\text{ACC}}$ Pinguin?
Which animal hugs the penguin
b. Which animal hugs the mouse?

(4) a. Welches Tier umarmt der$_{\text{NOM}}$ Pinguin?
Which animal does the penguin hug
b. Which animal does the mouse hug?

(5) a. Wo ist das Tier, das den$_{\text{ACC}}$ Pinguin umarmt?
Where is the animal that hugs the penguin
b. Where is the animal that hugs the mouse?

(6) a. Wo ist das Tier, das der$_{\text{NOM}}$ Pinguin umarmt?
Where is the animal that the penguin hugs
b. Where is the animal that the mouse hugs?

[1]We opted for simple present rather than present progressive, because learners at this stage have mostly been exposed to simple tenses. In addition, German does not grammaticalize aspect, and we wanted to keep the verb type identical across languages. As a consequence, English subject and object questions differ both in word order and by the presence of the auxiliary “do.” Critically, relative clauses—our dependent variable—differ only in word order.

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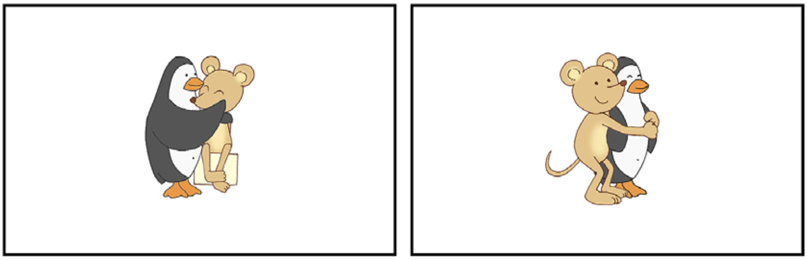

Figure 1. Visual display for sentences (3) to (6).

Unlike in English, the interpretation of German questions and relative clauses is not signaled by word-order changes; instead, case marking on articles expresses the grammatical role of a noun phrase for masculine nouns (whereas feminine and neuter nouns are fully ambiguous). For the German version of the experimental stimuli, the second-mentioned NP always had masculine gender. For instance, in (3a), the canonical subject interpretation of the question is marked by the second NP carrying accusative case, which designates it as the object. Critically, the word order of German object questions (4a) does not map on the word order of the corresponding English object question in (4b), and the word order of object relatives in (6a) is ambiguous between subject and object relatives. As a consequence, L1 German L2 learners of English cannot simply map German word orders onto their English equivalents; instead, for the L1 to facilitate L2 comprehension, they would need to engage joint revision mechanisms in sentence processing.

We decided to use ambiguous NPs (*which animal*) rather than referential nouns in the first NP (e.g., *which penguin*), as the latter give rise to stronger garden paths than ambiguous NPs. For strong garden paths, especially younger learners have been shown to stick with the original interpretation and fail to initiate reanalysis once they have settled on an interpretation (Trueswell et al., 1999). As a consequence, the study investigates how learners construct the noncanonical word order as opposed to the preferred canonical word order when they encounter the second noun that fully disambiguates the question or relative clause word order. When they hear this disambiguating information, they need to inhibit the prepotent canonical word order and revise their interpretation to the noncanonical word orders. Such revision is expected to be associated with delayed looks to the picture depicting the interpretation corresponding to the noncanonical order, longer reaction times, and lower comprehension accuracy.

The visual stimuli were adapted from Kidd, Chan & Chiu (2015) and Schouwenaars (2018) and partially modified/complemented by additional drawings. Each picture depicted two animals that were either the agent or the patient of the same transitive event (e.g., hugging). In each trial, one picture was the target image displaying the action that matched the presented sentence, and the other picture was the competitor image displaying the reversed structure (see Figure 1).

The sentences were recorded, spoken at a moderate pace, using natural intonation, by a German-English bilingual female speaker. The sentences in (3–6) were distributed across six lists, resulting in each participant hearing 60 sentences (10 sentences per condition: animate subject wh-question, animate object wh-question, inanimate subject wh-question, inanimate object wh-question, subject relative clause, and object relative clause) in each experiment. Additionally, 30 subject questions were presented as filler items that used two pictures that differed in the event depicted (e.g., *hug* vs *push*), so that disambiguation occurred via the verb rather than the word order or case marking. This resulted in 90 items presented in randomized order for each experiment. The positions of target and competitor picture as well as that of the agent within each picture were counterbalanced across conditions.

Procedure

Testing took place in two labs at the Universities of Braunschweig and Dortmund, which hosted the same equipment. Before the eye-tracking experiment, the participants were familiarized with the pictures of the animals, they named them in German and English, and received feedback and correction to ensure they accurately identified (the name of) each animal. The visual-world experiments were implemented in SR Research Experiment Builder (SR Research, 2020) and displayed on a 16:10 screen. Participants' eye movements were recorded with an EyeLink Portable Duo eye tracker with a tracking rate of 500 Hz. Participants sat approximately 60 cm away from the screen, and only their right eye was tracked. The participants' task was to decide which of the two pictures matched the auditory cue by pressing one of two buttons on a MilliKey MH-5 button box.

Prior to the actual experiments, participants performed a 5-point calibration. All trials began with a manual drift correct item that was presented in the middle of the screen and additionally served as a calibration check. This was followed by a 1,500 ms picture preview. After this time had elapsed, a question was presented auditorily and participants had 3,000 ms time after audio offset to make a decision (i.e., press a button). Participants were allowed to change their decision in the given time window as often as they wished to do so. After the entire time window, the next trial was initiated with a drift correct. Participants were presented with 10 practice trials in the English task version and three practice trials in the German version to familiarize them with the task. All participants were tested individually in a sound-attenuated booth. Each eye-tracking experiment took approximately 20 min. All participants took the eye-tracking task in English before the German version so as to avoid carryover effects from the dominant language.

Additionally, the participants completed several background tasks that were selected based on those used in previous studies. As mentioned above, they completed semantic fluency tasks in German and English and the Cross-Linguistic Lexical Task in English for proficiency. As cognitive tasks assessing cognitive capacity, they completed standardized nonverbal working memory (Corsi blocks tapping task; Corsi, 1972) and forward and backward digit span tasks (Wechsler, 2009). For cognitive control, they completed the nonverbal, standardized Flanker task (Eriksen & Eriksen, 1974) and a standardized verbal Stroop task in their dominant language, German (Stroop, 1935). The cognitive tasks were administered in Open Sesame (Mathôt et al., 2012), and the Corsi blocks task was administered in PEBL (Mueller & Piper, 2014). In total, the entire testing session took approx. 120 min including sufficient time for breaks for participants when needed.

For the CLT and the semantic fluency tasks, we computed scores reflecting the total of words named correctly. For the forward and backward versions of the digit span task, we calculated the memory span in terms of the overall number of trials remembered correctly, which was equal to the minimum list length (which is always 2) plus the total number of correct trials divided by the number of spans at each length (which is always

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2; Mueller & Piper, 2014). For the Flanker and Stroop tasks, effect magnitudes were calculated as indices of inhibitory control by subtracting the mean reaction times for incongruent trials from those of congruent trials.

Results

In the first step of the analysis, we present the results at the group level for the timing, latency, and success of the comprehension of noncanonical orders in the L1 (Experiment 1) and in the L2 (Experiment 2). All data were preprocessed in SR Research Data Viewer (SR Research, 2020) and then exported in .csv files for data processing in R (version 4.2.0). We analyzed the accuracy data using mixed-effects logistic regression modeling, and we employed mixed-effects linear regressions for the RT and the gaze data in the *lme4* (Bates et al., 2015) and *lmertest* package (Kuznetsova et al., 2017). For RTs and comprehension accuracy, only the first button press of each trial was included in the analyses. For RTs and gaze data, trials were excluded from the analysis when the decision was incorrect or when it occurred either before NP2 or more than 2,500 ms after sentence offset. In all, 31.84% of the data was excluded from the RT and gaze data analyses across both experiments and 6,217 trials remained for analysis, 3,251 in Experiment 1 and 2,966 in Experiment 2. Table 2 lists the comprehension accuracy and the response times for the respective conditions in the two languages.

In L1 German (Experiment 1), comprehension accuracy was high across the board, suggesting that all participants can successfully process and comprehend noncanonical sentences in their dominant L1. RTs tended to be slower for object-first than for subject-first orders. In L2 English (Experiment 2), there was a pronounced difference in comprehension accuracy and RTs between subject and object orders, bearing out that object orders are associated with greater comprehension difficulty and processing effort. In an omnibus analysis of the accuracy across languages and structures, we ran a mixed-effect logistic regression with the fixed-effects Structure (treatment coded: ref = questions), Word Order (treatment-coded: ref = subject), and Language (treatment coded: ref = German) and the maximal random effect structure permitted by the design that converged.[2] The model returned a main effect of Language (ß =-1.17; $SE = 0.16$; $t = -7.40$, $p < .001$), a significant Language × Word Order interaction (ß = 0.76; $SE = 0.19$; $t = 3.97$, $p < .001$), and a three-way Structure × Word Order × Language interaction (ß =-1.27; $SE = 0.25$; $t = -5.00$, $p < .001$). These findings indicate that English sentences were harder to understand than German sentences, and additional subset models show that object orders in English were more difficult than subject orders (ß = -0.85; $SE = 0.16$; $t = -5.385$, $p < .001$) and English object relatives were harder than English object questions (ß = -0.68; $SE = 0.14$; $t = -4.927$, $p < .001$).

Figure 2 shows looks to the target pictures following the onset of the second noun, when the sentences have been fully disambiguated syntactically. As can be seen for L2 English in the top panels of Figure 2, looks to targets increase sooner for canonical word orders than for noncanonical word orders. For L1 German, shown in the bottom panels, this difference is much less pronounced, indicating that the participants have

[2]The maximal converging model, derived via the 'order' function in R in the *buildmer* package (Voeten, 2021) was as follows: DV: Accuracy; IV: 1 + Language + Word Order + Language:Word Order + Word Order + Word Order:Structure + Language:Structure + Language:Word Order:Structure + (1 + Word Order + Language + Word Order:Language + Structure + Word Order:Structure | Participant) + (1| Item).

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Table 2. Accuracy and reaction times by language and condition

	Experiment 1: L1 German		Experiment 2: L2 English	
	Accuracy (%)	Reaction times (ms)	Accuracy (%)	Reaction times (ms)
Subject questions	91 (88.7–93.1)	733 (332)	86 (83.3–88.8)	875 (360)
Object questions	90 (87.3–92.0)	797 (271)	64 (58.4–69.1)	1058 (448)
Subject relatives	90 (87.9–92.3)	725 (275)	90 (87.6–91.2)	846 (352)
Object relatives	88 (85.2–90.4)	751 (312)	56 (50.4–62.8)	1022 (442)

Note. The values for 95% confidence intervals were calculated through nonparametric bootstrapping in parentheses for accuracy. Standard deviations in parentheses for RTs (n = 114).

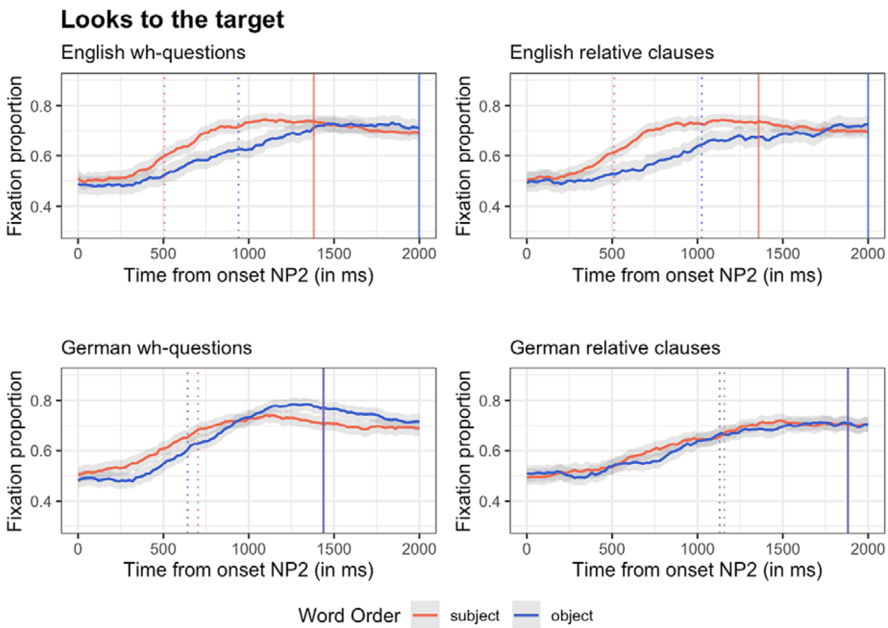

Figure 2. Proportion of looks to target picture over time by word order and by language. 0 ms denotes onset of NP2. All participants (n = 114); accurate responses only. Error bands show the 95% confidence interval. Dotted lines show mean sentence offsets for subject and object questions and RCs, respectively. Solid lines show mean RTs for subject and object questions and RCs.

much less difficulty with revising their parse to an object-initial order in the L1 than the L2.

For the subsequent regression modeling of the data for English relative clauses in Experiment 2—our structure of interest—we used accuracies and RTs, as well as the gaze data. To capture online effects reflecting the initial (re)analysis after the disambiguating cue and before a final decision was reached, we defined a time window

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of 250–750 ms after the onset of the second noun.[3] For this time window, we computed the ELOGs by analyzing the logits of the proportion of looks to the correct picture relative to the incorrect picture, log[Prop/(1-Prop)]. For the analysis of looks, we added a value of 0.05 to the numerator and the denominator to avoid values of exactly 0 or 1, which are undefined. To be able to compute effects of intra- and interlinguistic processing relations, we calculated the mean difference scores per participant between the relevant conditions for accuracy, RTs, and ELOGs. This predictor indexes the facility of reanalysis to object orders in a different construction (questions vs. relative clauses) or a different language (L1 vs. L2). For instance, to quantify reanalysis facility for questions, we calculated the mean difference between object and subject accuracy per participant for questions, and we included this measure as a predictor in the model. A positive value or a value close to zero indicates no or low difficulty with object orders compared with subject orders, whereas a negative difference score shows that object orders were more difficult to comprehend than subject orders. Similarly, we calculated the mean difference between object and subject question latencies per participant, and we included this measure as a predictor in the model. Finally, we included analogous predictors from German questions to English questions and from German relative clauses and English questions to English relative clauses. We deliberately selected the *difference score* as an appropriate measure of reanalysis rather than, for instance, the absolute accuracy or reaction times in the related object conditions. As accuracy and reaction times for sentences with noncanonical word orders need to be seen relative to accuracy and reaction times for sentences with canonical orders, using the difference scores serves as a baseline correction. To illustrate, if a participant has low comprehension accuracy of object relative clauses, this may indicate difficulty in comprehending such noncanonical orders. However, if comprehension accuracy on the canonical subject relative clause order is equally low, comprehension may generally be low in the experiment, due to, for example, lack of concentration or fatigue. To correct for such baseline differences in comprehension, we chose to use the difference scores as a measure of an individual's reanalysis ability. To ensure that the difference scores in RTs and ELOGS are representative of the reanalysis ability of an individual, we followed previous studies by analyzing only participants who had data from at least three trials out of 10 trials with correct interpretations in this condition and measure (Hopp & Grüter, 2023).

In all models subsequently reported, we used treatment coding for the fixed effect of word order, with subject orders as the reference level, as we are interested in the reanalysis costs of object compared with subject orders. All other fixed effects were continuous measures and were entered as scaled and centered predictors, including their interactions with word order and trial number (to control for changes in the course of the experiment). As fixed effects, we entered the following cognitive and linguistic measures. As cognitive predictors, we entered the Flanker and Stroop effects, the forward and backward digit span scores, and the nonverbal memory span score. As linguistic predictors, we entered the two L2 proficiency measures and the respective difference scores for the comprehension of questions in the L2. We also added the difference scores for the comprehension of relative clauses in the L1. We used the

[3]We also ran exploratory analyses in a longer and later time window that partially extends beyond the time when participants had made their responses (500 ms to 1,500 ms after N2 onset). These analyses returned a pattern of effects comparable to those of the models for the earlier time window reported in the text. In the present paper, we restricted the analysis of eye movements to proportion of looks in time windows, as the present study is not interested in nonlinear effects of time but only the relative degree of difficulty with object-first orders. Future analyses could further investigate the time course of effects in the eye movements.

buildmer package (version 2.3; Voeten, 2021) to identify the best-fitting model. Using the 'order' command, we first calculated the maximal models that converged for accuracy, reaction times, and gaze data (see Table S2 on the project's OSF page). Second, we added the 'backward' command to initiate automatized model comparisons to identify the best-fitting converging model that retained at least random intercepts. These optimal models are reported in the tables below.

Table 3 lists the optimal models for relative clauses (for questions, see Table S1 on the project's OSF page). For each model, the tables also list the number of participants who were included in the respective analysis. There were consistent main effects of word order across the measures, which bears out that object relatives were associated with greater difficulty in the initiation, completion, and success of reanalysis. Further main effects surfaced for proficiency in RTs, the L1 difference score in RTs and accuracy, and the Flanker effect in RTs. Given our interest in which factors modulate reanalysis, we focus on significant interactions with word order in the following. The models returned consistent interactions with the difference score for English questions in the gaze data, the reaction times, and accuracy. For accuracy, the interaction with proficiency also became significant. In addition, there was a significant interaction with the L1 difference score for relative clauses in the RT data.

The interactions with the difference scores are visualized in Figure 3. As seen in Figure 3, the initiation, completion, and success of reanalysis for object relative clauses were modulated by the respective difference scores for questions in that greater facility in reanalyzing object questions was associated with greater facility of revising object relatives. As for the interaction of the L1 difference score with RTs in the L2, it went in the opposite direction: RTs to English object relatives were faster the larger the difference score was for German relative clauses. In other words, participants who had more difficulty with German object compared to subject relative clauses were quicker in responding to English object relatives and slower to respond to English subject relatives. In addition, the model for comprehension accuracy returned significant interactions of word order with the two measures of working memory. As Figure 4 shows, higher forward and backward memory spans are significantly associated with higher accuracy in object relative clauses. There were no further significant interactions with word order.[4]

Discussion

In the present study, we explored cognitive and linguistic predictors for the comprehension of relative clauses among low-proficiency L2 learners. Specifically, we asked whether the comprehension of object relative clauses that require successful reanalysis is aided (a) by reanalysis facility in a less challenging noncanonical structure in the L2—namely, questions; (b) by reanalysis facility of relative clauses in the L1; or (c) by cognitive capacity or inhibitory control. Across several measures, the study found that L2 learners could rely on reanalysis skills applied to a different grammatical structure in the L2 and partly also those applied to the same structure in the L1. In addition,

[4]To make sure that potential effects of cognitive predictors on reanalysis were not masked by their mediation in the difference scores for English questions and German relative clauses, we also ran models without the two difference scores as predictors (see Table S3 on the project's OSF page). Like the models reported in the text, these models did not yield any interactions with Word Order for any of the cognitive predictors.

Table 3. English relative clauses: Model outputs after model optimization via *buildmer* (empty cells mean that the predictor was not included in model). Significant effects in bold.

		Accuracy (*n* = 114)			Reaction times (*n* = 104)			Gaze data—ELOGS 250–750 ms (*n* = 96)		
		Estimate	*SE*	*t*	Estimate	*SE*	*t*	Estimate	*SE*	*t*
	Intercept	2.51	0.19	13.121***	693.79	42.68	16.256***	0.64	0.08	7.741***
	Trial no.	**−0.39**	**0.11**	**−3.450*** **	**2.83**	**0.54**	**5.233*** **			
	Word order	**−1.49**	**0.23**	**−6.392*** **	**126.99**	**28.47**	**4.461*** **	**−0.47**	**0.13**	**−3.687*** **
	Word Order × Trial No.	**0.56**	**0.14**	**4.068*** **						
Linguistic predictors - within L2	CLT score	0.13	0.16	0.824	**−135.11**	**30.29**	**−4.461*** **			
	Fluency score	0.25	0.16	1.623						
	L2 difference score (wh-questions)	−0.64	0.45	−1.435	−44.71	31.01	−1.442	**−0.16**	**0.08**	**−1.978* **
	Word Order × CLT Score	**0.61**	**0.21**	**2.940** **						
	Word Order × Fluency Score	**−0.40**	**0.19**	**−2.080* **						
	Word Order × L2 Difference Score (wh-questions; in respective measure)	**3.08**	**0.56**	**5.493*** **	**100.01**	**28.70**	**3.485*** **	**0.26**	**0.13**	**2.052* **
- across languages	L1 Word Order Difference Score	**0.24**	**0.10**	**2.335* **	**87.00**	**29.66**	**2.933** **			
	Word Order × L1 Word Order Difference Score				**−62.03**	**28.69**	**−2.162* **			
Cognitive predictors	Flanker effect				**−57.71**	**28.69**	**−2.011* **			
	Digit span forward	−0.24	0.16	−1.489						
	Digit span backward	0.29	0.17	1.674						

(*Continued*)

Table 3. (*Continued*)

	Accuracy (n = 114)			Reaction times (n = 104)			Gaze data—ELOGS 250–750 ms (n = 96)		
	Estimate	*SE*	*t*	Estimate	*SE*	*t*	Estimate	*SE*	*t*
Word Order × Digit Span Forward	**0.48**	**0.21**	**2.316***						
Word Order × Digit Span Backward	−**0.440**	**0.213**	−**2.067***						
	Formula: acc ~ 1 + Word Order + EN_acc_diff_wh + Word Order:EN_acc_diff_wh + CLT_score + DE_acc_diff_RC + Word Order:CLT_score + Digit_span_bw + Word Order: Digit_span_bw + Digit_span_fw + Word Order: Digit_span_fw + Trial + Word Order:Trial + Fluency + Word Order:Fluency + (1 + Word Order | Participant) + (1 | Item)			Formula: RT ~ 1 + EN_RT_diff_wh + Trial no. + CLT_score + Word Order + DE_RT_diff_RC + Flanker + EN_RT_diff_wh:Wor Order + Word Order:DE_RT_diff_RC + (1 | Participant) + (1 | item)			Formula: Elog ~ 1 + Word Order:EN_ELOG_diff_wh + (1 | Participant) + (1 | Item)		

Note.
**p* < .05; ***p* < .01; ****p* < .001.

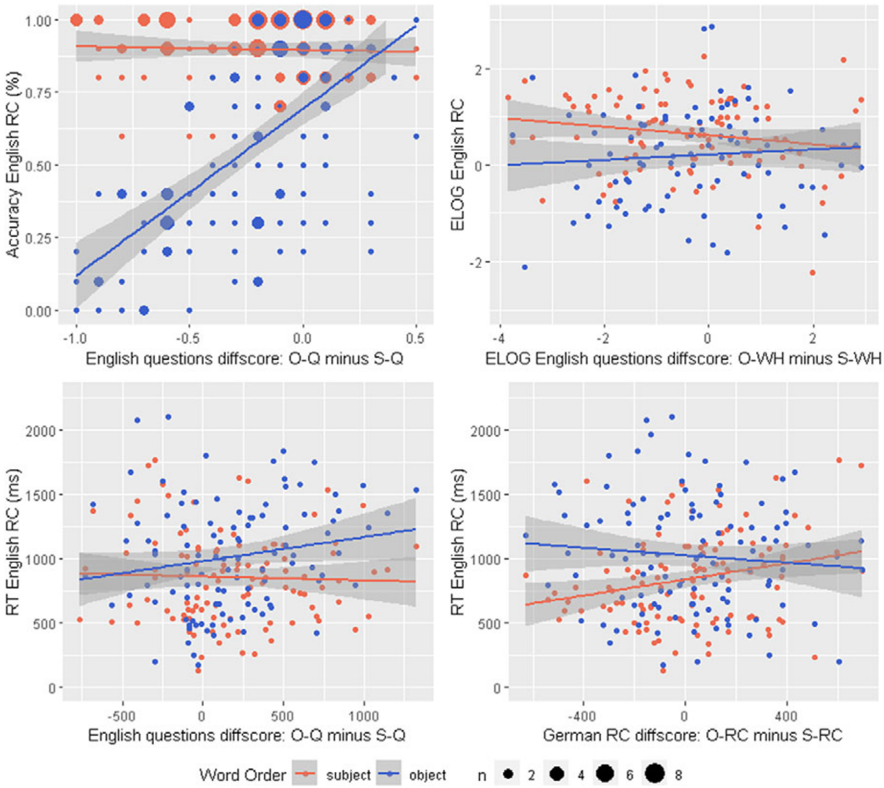

Figure 3. Relative clauses in English: Interactions for accuracy (top left), ELOGs (top right), and RTs (bottom left) with difference score in English questions. Interactions for RTs with difference score in German relative clauses (bottom right). In accuracy or ELOGs (i.e., gaze data), a higher difference score indicates less difficulty with object orders than with subject orders. In reaction times, a smaller difference score indicates less difficulty with object vs. subject orders.

sentence comprehension accuracy was also associated with working memory. In contrast, there were no interactions of word order with cognitive control. In the following, we first briefly discuss the findings at the group and individual level, then discuss the results in light of our research questions, and finally outline the consequences for the role of processing in learning.

At the group level, processing and comprehension in the L1 were more target-like than in the L2. As seen in Table 2, compared with their comprehension of questions and relative clauses in their L1, the larger standard deviations suggest that there was decidedly greater variance between participants in L2 sentence comprehension, as would be expected for low-level proficiency L2 users who are in the process of acquiring complex sentences in the L2. Among these, questions proved easier to comprehend, as indicated by the higher accuracy scores for object questions (64%) than for object relative clauses (56%). As for our structure of interest, the models for relative clauses showed that object relatives differed from subject relative clauses in the initiation of reanalysis, the completion of reanalysis, and the success of reanalysis.

In terms of individual differences, there were two types of interactions with word order, one with measures of linguistic reanalysis skills and the other with measures of cognitive processing. In the gaze data, in the RTs, and in comprehension accuracy, the

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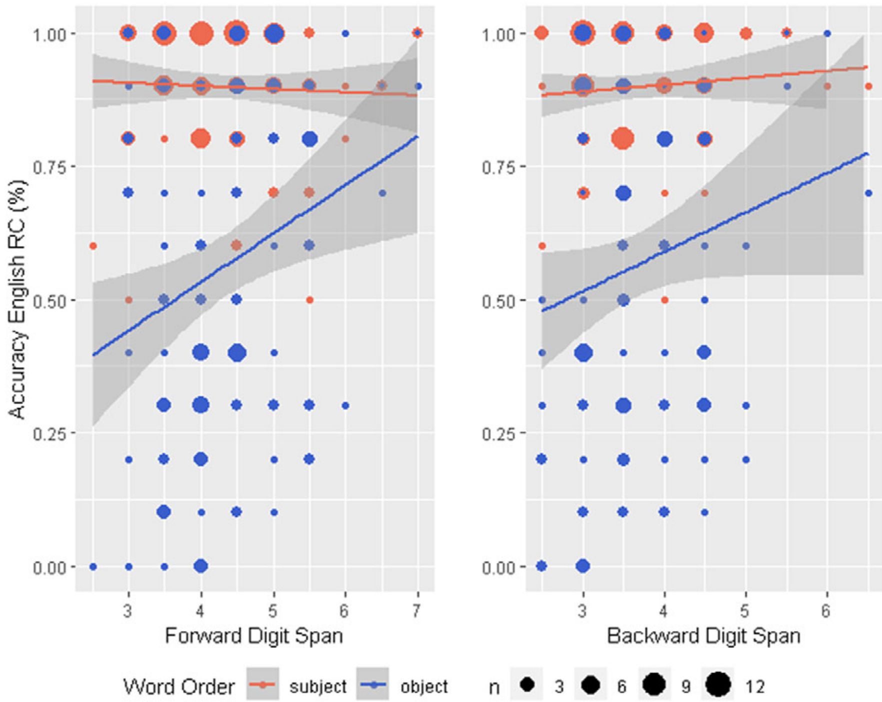

Figure 4. Relative clauses in English: Interactions for accuracy with forward digit span (left) and backward digit span (right).

interactions with the respective difference scores for English questions, visualized in Figure 3, show that learners who were quick to initiate and complete reanalysis to object questions were also faster to initiate and complete reanalysis in object relative clauses. The success in completing reanalysis for object questions also translated into greater comprehension accuracy for object relative clauses.

With respect to RQ1 about within-language processing effects, these effects provide robust evidence for intralanguage processing relations in that the reanalysis ability for a less challenging noncanonical L2 word order is related to reanalysis in a more challenging word order. Note that these interactions are significant even when L2 proficiency is accounted for in the models. Thus, L2 reanalysis skills with a less challenging noncanonical order appear to constitute a learning resource over and above a learner's general command of an L2. Critically, they also hold when cognitive factors that could potentially modulate reanalysis ability are controlled for, such as working memory or inhibitory control. Such contingencies underscore that the same sentence processing and revision mechanisms apply in object questions and relative clauses also among beginning L2 learners, and—critically—that learners can capitalize on these shared reanalysis mechanisms when acquiring complex syntax.

Alternatively, at a less abstract level, the facilitation from object questions to object relatives might be due to structural priming in that the previous encounter of an object question may directly facilitate the comprehension of object relative clauses because they map to the same interpretation. Although we cannot rule out effects of priming, as the same experiment contained both object questions and object relatives, the effect

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structure regarding effects of trial number does not appear to support a priming account straightforwardly. The models did not return any consistent interactions of word order and trial number that would point to cumulative priming—that is, learning in the course of the experiment as a result of priming from questions to relative clauses. Moreover, none of the models returned a significant three-way interaction of word order, trial number, and difference score that would indicate that the effects of processing facility with questions on object relatives only emerge in the course of the experiment. Instead, the significant main effects of trial number in RTs and comprehension accuracy demonstrate that the learners became slower and less accurate as the experiment unfolded. For accuracy, the significant interaction with word order signals that accuracy for object orders increased while it decreased for subject orders. Such changes arguably index learners' growing discrimination of subject and object orders as learners increasingly allow for a remapping of thematic roles and word order. The finding that effects of intralanguage processing relations do not seem to emerge over the course of the experiment but hold throughout it suggests that it is the recruitment of the same sentence revision mechanisms across structures that boosts the comprehension and acquisition of object relative clauses.

As for RQ2 about between-language processing effects, the difference score for relative clauses in L1 German was a significant predictor for the RTs to object relative clauses in English. As seen in Figure 3 (bottom right), RTs to English object relatives were responded to faster the larger the difference score was in German relative clauses. Prima facie, this appears to be a surprising result because slower processing of German object relatives vis à vis subject relatives would lead to faster responses for English object relatives. Upon closer inspection, though, the effect may be driven by a particular processing strategy. If participants base their decision on a partial parse of the noun and verb within the relative clause, they arrive at a faster interpretation of a German object relative clause ("~~Wo ist das Tier, das~~ [der$_{NOM}$ Hund jagt]"—*the dog$_{SUBJ}$ hunts*) as a partial SV parse than a German subject relative ("~~Wo ist das Tier, das~~ [den$_{ACC}$ Hund jagt]"—*the dog$_{OBJ}$ hunts*), since the N-V combination in a subject relative corresponds to a local noncanonical, object-first order. When applying the same strategy to English relative clauses, object relatives also become easy to comprehend as partial SV orders (*~~Where is the animal that~~ the dog chases?*), while subject relative clauses cannot easily be interpreted within such a partial parse (*~~Where is the animal that~~ chases the dog?*). Though speculative, this account captures the interlinguistic processing relations observed in the RTs for relative clauses by assuming that some learners apply a locally coherent SV(O) parse. Local coherence effects have been reported for both L1 speakers and L2 learners in several reading studies (for L1, Tabor et al., 2004; for L2, Hopp, 2017). In the study by Hopp (2017, Experiment 1), locally coherent parses were more common among less proficient L2 learners, which suggests that partial parsing may be a strategy employed by L2 learners to overcome difficulties in integrating information across larger dependencies. Instead, they retain locally coherent parses even when they are not licensed by the global sentence context. We leave it to future research to examine such potentially different learner strategies further.

Overall, however, there was little influence from the L1 to the L2 comprehension of relative clauses, which suggests that reanalysis skills in the L1 may not facilitate reanalysis of the same structure in the L2. In part, the absence of effects of L1 processing may stem from the high comprehension accuracy of object relative clauses in German that the learners had achieved. In future studies, it may be interesting to address bilingual learners in earlier developmental stages in their L1 grammatical development. In addition, it will be fruitful to examine different L1-L2 combinations. In the present study, we strove to isolate L1-L2 effects at the level of processing. For this reason, we chose to investigate German learners of English, because German and English encode form-meaning mappings in questions and relative clauses by different means (inflection vs. word order). There may be more evidence for L1 effects if—on top of recruiting shared revision mechanisms in processing—learners can directly map the L1 word order onto the L2 word order in sentence comprehension.

In relation to RQ3 about the role of cognitive factors, the study also unearthed a few interactions with cognitive factors. As opposed to the early and continuing effects of linguistic predictors, effects of cognitive predictors emerged only in RTs and accuracy, which suggests that cognitive factors affect the later integration and interpretation of noncanonical orders more than their initial processing. Working memory constituted a significant predictor in comprehension accuracy, as seen in the interactions with forward and backward memory span. Such a finding is in line with many studies on L1 and L2 processing that report working memory effects on the comprehension of relative clauses (for L1, Arosio et al., 2012; Hussey et al., 2017; for L2, Cheng et al., 2021; Hopp, 2014). In serial-processing models, the object-first structure imposes a particular load on working memory, as participants need to hold the relative clause pronoun *that* in memory for longer and link it to the appropriate grammatical role subcategorized for by the verb. In parallel models of sentence processing, both analyses are assumed to be partially computed and participants need to carry out reanalysis by reranking them. The interactions with working memory in comprehension accuracy indicate that participants with higher memory spans were better able to compute the object structure and/or hold it active in memory in parallel with the subject structure to ultimately select the former over the latter.

Among other cognitive predictors, solely the Flanker effect became significant as a main effect in the RT analysis, indicating that a larger Flanker effect, indicating poorer inhibitory control, was associated with generally faster RTs. The absence of any interactions of measures of inhibitory control with word order suggests that the degree to which reanalysis processes among low-proficiency L2 learners are tied to their executive function is limited. At face value, and pending possible effects that may be found in a much larger sample, the lack of effects of inhibitory control in L2 processing may suggest that inhibitory control mechanisms do not contribute to the processing of noncanonical word orders. We are cautious in this interpretation for several reasons. First, the two tasks used for assessing inhibitory control, the Stroop and the Flanker task, may not sufficiently tap those inhibitory control processes that are required for reanalysis of noncanonical constructions (but see Woodard et al., 2016; Ye & Zhou, 2009; see also Poarch & Van Hell, 2019, for a discussion of convergent validity between EF tasks). Second, our participants acquired an L2 and were cognitively much more mature than child L1 learners with lower cognitive control skills (Kidd et al., 2011) or child L2 learners below their teens (Cristante, 2016). It may be that adolescent learners already possess too advanced control skills across the board such that individual differences in cognitive control ability no longer surface in language comprehension. However, the main effects of Flanker inhibition on reaction time suggest that individual differences in cognitive control at least globally affect the speed of sentence comprehension in learners at this age. Third, we used sentences that were initially ambiguous in their interpretation of the first NP (*which animal*). Other studies on reanalysis have used referential nouns (e.g., *the cat*) in questions like “Which cat hugs the donkey?/ Which cat does the donkey hug?” Referential first nouns lead to a stronger commitment to the scene with the cat as agent for the initial parse than an ambiguous NP. It may be

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the case that participants needed to exercise less inhibitory control to suppress the subject parse with ambiguous NPs than when a partial commitment to an interpretation needs to be undone. Accordingly, effects of inhibitory control may surface when more of it is required. Finally, inhibitory control effects among L1 learners or speakers were previously predominantly reported for temporary ambiguities with garden-path sentences (Hsu & Novick, 2016) yet less for noncanonical orders in which the surface word order does not map to canonical grammatical and semantic roles (but see Thothathiri et al., 2018). In fact, Hussey et al. (2017, pp. 44–45) surmise that comprehension of (object) relative clauses may not draw on conflict-control procedures but instead indexes memory constraints arising from dependency completion. The findings of the present study showing effects of working memory, yet not of inhibitory control, are compatible with the suggestion that reanalysis for sentences with noncanonical word order is less susceptible to the involvement of cognitive control than conflicts created by garden-path sentences. All in all, then, the present study thus does not furnish any evidence to suggest that domain-general inhibitory control mechanisms constitute a primary mechanism in the L2 processing or acquisition of noncanonical orders.

At the same time, the linguistic processing relations found within the L2 point to the involvement of non-structure-specific reanalysis mechanisms in the L2 acquisition of noncanonical word orders: individual differences between learners in their reanalysis ability in object questions affect reanalysis in relative clauses. These findings demonstrate that language processing is implicated in the acquisition of complex syntax in that processing skills with an earlier or more fully acquired structure facilitate the learning of a more challenging related structure. Future research should investigate to which degree the present findings generalize across other, less related or unrelated noncanonical orders requiring reanalysis, such as passives or garden-path sentences. Moreover, it will be interesting to study whether and how immediately prior experience with reanalysis from one trial to the next affects comprehension. We are exploring these issues in ongoing priming experiments, not least due to their applied consequences. In a foreign language classroom, if learners are exposed to a simpler, more frequent, or earlier-acquired structure that involves similar processing mechanisms before they encounter a more complex sentence, they may experience critical processing episodes allowing them to acquire a more complex grammatical structure.

In summary, this exploratory study on how learners process to learn shows that shared sentence processing and reanalysis mechanisms implicated across different grammatical structures, rather than differences in cognitive processing associated with sentence revision, aid L2 learners in comprehending noncanonical word orders that they are beginning to acquire. In this respect, the findings of the present study underscore the contributions of language processing to learning.

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Data availability statement. The experiment in this article earned an Open Data badge for transparent practices. The materials, data, code and analyses for the results reported in the paper are available at https://osf.io/ux735/.
The picture stimuli are copyrighted and can be obtained from the authors upon request.

Competing interest. The author(s) declare none.

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