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## EMPIRICAL STUDY

# Second Language Learning via Syntactic Priming: Investigating the Role of Modality, Attention, and Motivation

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**Abstract:** We examined whether input modality and individual differences in attention and motivation influence second language (L2) learning via syntactic priming. In an online study, we compared the primed production of English passives by 235 L2 and native English speakers in reading-to-writing versus listening-to-writing conditions. We measured immediate priming (producing passives immediately after exposure to passives) and short- and long-term learning (producing more passives in immediate and 1-week delayed posttests relative to pretests). Both groups showed immediate priming and short- and long-term learning, although L2 speakers produced more passives with immediate priming and showed greater long-term learning. Learning was unaffected by modality, but immediate priming was greatest in the listening-to-writing condition across groups. Individual differences in attention and motivation did not influence priming or learning. Thus, syntactic priming fosters long-term L2 learning regardless of input modality, but participants may be sensitive to the frequency of passives in spoken versus written language during immediate priming.

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## Introduction

Second language (L2) speakers, like first language (L1) speakers, tend to adopt the syntactic structure of recently experienced sentences to formulate subsequent sentences, in a phenomenon known as syntactic priming (Bock, 1986; McDonough & Chaikitmongkol, 2010). For example, exposure to a passive (prime) sentence (*the song is being played by the musician*) may increase L2 speakers' likelihood of producing a passive (target) sentence (*the teacher is being imitated by the student*) compared to exposure to an active sentence (*the musician is playing the song*). Researchers have hypothesized that adaptive language-learning mechanisms underlie syntactic priming effects (Bock & Griffin, 2000), and indeed these effects are long-lasting in L2 speakers: L2 speakers' prior experience of prime sentences influences their sentence formulation in posttests that follow the priming session immediately or a few weeks later (e.g., McDonough & Chaikitmongkol, 2010). Priming tasks also help L2 speakers learn how to produce nativelike L2 structures over successive experiences of L2 input (e.g., Y. Kim et al., 2019). These findings suggest that syntactic priming may underlie the acquisition of L2 syntactic knowledge (Jackson, 2018).

Many task and learner characteristics that potentially affect L2 learning via syntactic priming remain unexplored. It is unknown whether the modality of the language input influences L2 speakers' priming behaviour and the resulting syntactic learning. Moreover, how these might be related to individual variation in learners' attention and language-learning motivation is unclear. Understanding the respective roles of these variables can elucidate the extent to which L2 learning and syntactic priming are supported by language-learning mechanisms that are implicit and automatic or that are also susceptible to explicit processes. The present study therefore examined the effect of prime modality and individual differences in attention and motivation on L2 learning via syntactic priming.

## Background Literature

### Language Input Modality and Second Language Learning

Second language acquisition (SLA) researchers have not widely investigated which of the spoken and written input modes best supports L2 learning (Gilabert et al., 2016; Zhao et al., 2021). However, statistical learning studies

suggest that the brain may process auditory and visual input separately (e.g., Siegelman & Frost, 2015). One might reasonably predict that L2 speakers more easily learn a target syntactic structure experienced through the visual rather than through the auditory modality. When L2 speakers are presented with spoken input, the task of trying to decode speech may distract them. Written sentences, in contrast, may free up attentional resources and allow them to focus more on sentence form, making target structures more salient (Gilabert et al., 2016; K. M. Kim & Godfroid, 2019). Given its untimed nature, as opposed to the fleeting nature of auditory input, the written modality also gives L2 speakers the opportunity to read sentences repeatedly and rely on self-paced processing. This may foster deeper processing of the linguistic input: Rather than simply registering new linguistic information, L2 speakers may engage in intake processing, which should support language learning (Gilabert et al., 2016). Thus, written stimuli could facilitate L2 syntactic processing and language learning to a greater extent than spoken stimuli. Indeed, Wong (2001) found that L2 learners obtained better comprehension scores, as assessed with free recalls, with written than with spoken L2 input, suggesting that L2 speakers process written language more accurately than spoken language.

However, some research does not support this prediction. Artificial grammar and statistical learning studies indicate that the auditory modality supports learning better than the visual modality (e.g., Frost et al., 2019; Zhao et al., 2021). Other SLA studies show similar L2 learning and processing across input modalities. For example, Morgan-Short et al. (2018) found that learners' L2 comprehension was not affected by input modality. K. M. Kim and Godfroid (2019) directly compared the effect on L2 learning of exposure to written or spoken stimuli during a language training phase and found that both types of input modality led to the same amount of learning as measured on posttraining grammaticality judgment tests, although input modality did modulate the type of knowledge acquired. However, across training modalities, participants were asked to repeat the stimuli out loud during training, meaning that, even in the reading condition, participants received auditory input (Zhao et al., 2021). Therefore, understanding the effect of input modality on L2 learning requires further research.

### Syntactic Priming as Second Language Learning and Prime Modality

Syntactic priming provides one means for measuring language learning. Early psycholinguistic models explained syntactic priming effects in terms of residual activation associated with the representation of a given syntactic structure. Upon exposure of a speaker to a structure, its representation would retain

activation, leading the speaker to reuse that structure instead of its structural alternative (Pickering & Branigan, 1998). However, the persistence of priming effects (Bock & Griffin, 2000) suggests that priming is supported by a language-learning mechanism (e.g., Chang et al., 2006; Malhotra et al., 2008; Reitter et al., 2011). The implicit, error-based language-learning model (Chang et al., 2006) postulates that priming effects result from language acquisition processes still operating after L1 syntactic representations have been acquired. Listeners predict upcoming language, and mismatches between their predictions and the language input generate prediction errors that force adjustments to the connections between message-level information and syntactic representations. Speakers become more likely to subsequently use the same structure to express a similar message. These changes are lasting and therefore indicative of learning. Alternatively, in Reitter et al.'s (2011) model, syntactic nodes corresponding to target syntactic structures are associated with a base-level activation reflecting speakers' familiarity with the structures. Perceiving target structures results in long-term changes in this activation and triggers learning in terms of increased likelihood of using a particular structure to express a particular message in the future. Such effects are thought to be implicit and automatic.

L2 speakers experience long-term priming effects, indicating learning via priming (e.g., Grüter et al., 2021; McDonough & Chaikitmongkol, 2010). We can thus examine the effect of input modality on L2 learning by investigating how prime modality affects L2 priming strength. If L2 speakers process the L2 more deeply when reading than when listening (Gilabert et al., 2016; Wong, 2001), then written input could increase the magnitude of L2 immediate priming relative to auditory input. Concretely, written language input may support mismatch detection or the formation of predictions (Chang et al., 2006), or increase the likelihood of syntactic representations being activated (Reitter et al., 2011). Stronger priming is more likely to strengthen connections between message-level information and syntactic representations (Chang et al., 2006) or increase base-level activation (Reitter et al., 2011), leading to learning. Thus, L2 speakers should display more immediate priming when reading prime sentences than when listening to them. The degree of immediate priming should also determine the degree of long-term priming, such that, if L2 speakers are more likely to experience syntactic priming from one input modality, they should be more likely to show long-term learning from that modality too.

Few studies have explored the effect of prime modality on syntactic priming. A meta-analysis revealed that, in L1 speakers, priming strength is the

same across modalities, regardless of whether researchers use auditory or visual primes, or primes which participants read aloud (Mahowald et al., 2016). Moreover, L1 long-term priming effects are similar within each modality (Hartsuiker et al., 2008). By contrast, with respect to L2 priming, two studies found larger immediate priming effects in written chat-based interactions than in oral face-to-face ones (Y. Kim et al., 2019, 2020). This could suggest that, unlike L1 speakers, L2 speakers process syntax differently in the spoken and in the written modality. The latter findings could also indicate that the L2 speakers preferred to produce the target structures in the written than in the oral modality; further research is needed to investigate the effect of input modality on L2 priming and on the resulting long-term learning.

**Individual Differences in Second Language Learning**

Individual differences in learner characteristics could also influence the magnitude of L2 syntactic priming and the resultant learning. Both individuals' motivation to learn and their attention to the linguistic input have been shown to affect L2 learning (e.g., Robinson et al., 2012; Ushioda & Dörnyei, 2012), and this influence could vary depending on the nature of the task (see below). However, since the learning that results from syntactic priming is typically thought to be unconscious and implicit, it is not immediately obvious how current psycholinguistic models of priming as language learning can be linked to SLA research demonstrating that other cognitive processes influence L2 learning. On the other hand, syntactic priming may itself involve both implicit and explicit processes: Ferreira and Bock (2006) attribute greater priming in the syntax-focused condition of Bock et al.'s (1992) study to possible explicit memory or attentional effects strengthening learning. Furthermore, Chang et al. (2006) suggest that differences in individual characteristics, such as motivation and attention, may explain variation in priming magnitudes. Thus, individual differences in learner characteristics may be relevant to understanding how syntactic priming can support L2 learning.

*Motivation and Attention in Second Language Acquisition*

Individual differences in motivation and attention can influence L2 learning and achievement (Robinson et al., 2012; Ushioda, 2016; Ushioda & Dörnyei, 2012). SLA research shows that several types of motivation affect L2 production and achievement (Deci & Ryan, 1985; see also Cheng et al., 2014; Noels et al., 2001). Intrinsic and extrinsic motivation respectively reflect an inherent desire to learn a language for the affective rewards of engaging with learning activities (e.g., *I enjoy the experience of surpassing myself when*

*practicing English*) and learning in order to be rewarded or not to be punished (e.g., *I don't want to fail the English course*). High motivational intensity and high task motivation or positive attitude toward the task respectively reflect the strength of participants' engagement in language-learning activities (e.g., *I am working hard at learning English*; Gardner & Lambert, 1972) and a combination of task enjoyment (e.g., *I found the task interesting*; Eccles, 1993) with reported effort (e.g., *I put a lot of effort in doing the task*; Boekaerts, 2002; Noels et al., 2001).

Motivation could also determine what learners pay attention to during an interaction (Ushioda, 2016). Highly intrinsically motivated participants tend to notice target linguistic features more (Takahashi, 2005), and whether learners improve in L2 comprehensibility relates to how strongly they want to progress in that regard (Saito et al., 2017). Considering a task to be useful to reaching one's language-learning goal may also make participants more motivated and thus more attentive to it (Wigfield & Eccles, 2000). In other words, participants' learning goals may affect their strategies for focusing attention on certain aspects of the task.

Importantly, experimental manipulations that make L2 speakers more attentive to the stimuli containing the target structure, such as explicit instructions or other enhancement techniques, foster learning of these structures (Robinson et al., 2012). Furthermore, the noticing hypothesis (Schmidt, 1990) states that noticing a target structure (i.e., consciously registering a specific grammatical form in the stimuli) is necessary for learning it, and that noticing and understanding the target structure (i.e., also knowing the grammatical rules) facilitates learning further. Brooks and Kempe (2013) found that English L1 speakers who were able to describe the syntactic rules and structures present in experimental stimuli learned Russian inflectional morphology more successfully. SLA research thus shows that motivation and attention relate to L2 learning, but whether these variables could similarly increase L2 learning via syntactic priming remains largely unclear.

### *Motivation, Attention, and Syntactic Priming*

Current models of syntactic priming (Chang et al., 2006; Reitter et al., 2011) define syntactic priming and the resulting learning in particular as being largely implicit processes (error-based learning via prediction or activation of representations), in which case more explicit processes such as motivation and attention should not affect long-term priming (learning). According to the models of Chang et al. (2006) and Reitter et al. (2011), explicit memory processes can exert a short-lived influence on priming, particularly in the context

of priming with lexical overlap (Hartsuiker et al., 2008), but do not relate to the language-learning mechanisms of the models. Thus, L2 speakers motivated to learn the language could be more likely to (explicitly) choose to copy the structure of a L2 prime sentence in order to sound like their interlocutor or to practice the target language (Costa et al., 2008), and enhanced attention could help speakers to (explicitly) remember prime sentences better. High motivation and attention could therefore promote immediate reuse of a prime's structure but should not increase language learning via syntactic priming.

However, another possibility is that enhanced motivation and attention could increase learning because they contribute to the processes that underlie language learning via syntactic priming. Being highly motivated or attentive could support the formation of predictions about the upcoming linguistic input (see Grüter et al., 2021, for discussion), which drive the learning process when it is erroneous (Chang et al., 2006). Alternatively, greater motivation and attention, if they lead to deeper processing of prime sentences (Branigan et al., 2007), could strengthen the mappings between message-level and structural representations and thus foster larger changes in connection weights, in the framework of Chang et al.'s (2006) account (see also Ferreira & Bock, 2006), or larger activation of syntactic nodes, in the model of Reitter et al. (2011; see Branigan et al., 2007, and Ivanova et al., 2020, for similar reasoning). Consequently, if more motivated and attentive participants experience these deeper effects of immediate priming, they should also experience larger long-term effects.

No study has investigated the relationship between motivation and priming, and there is limited research examining whether attention influences L2 learning via syntactic priming. Past research, largely conducted with L1 speakers, provides preliminary (and mostly indirect) evidence that speakers experience more immediate priming when they are more attentive to the syntax of stimuli or to the priming task in general. L1 speakers instructed to pay attention to the syntactic form of the stimuli rather than to their semantic content show increased priming effects (Bock et al., 1992). Likewise, participants experience more priming when completing a shared goal with their interlocutor (Reitter & Moore, 2014) or when they hear primes in a dialogue or directly addressed to them rather when they hear primes in a monologue or as side participants (Branigan et al., 2007; Schoot et al., 2019; but see Ivanova et al., 2020). These conditions may all make participants more attentive to the task and its stimuli in order to help participants achieve the task or mutual understanding with their interlocutor. One study assessed L1 speakers' individual differences in attention to task more directly: Ivanova et al. (2020) measured participants'

reaction times on a picture verification task performed in parallel to a priming task, assuming that lower variability in reaction times when performing this secondary task would reflect higher levels of attention to the main priming manipulation. Reduced variability in reaction times was indeed associated with larger priming effects, suggesting that attention to task increases priming. With L2 speakers, being more attentive to syntax and noticing the target structure seems to increase immediate priming. In one study, only learners who detected the target form experienced immediate priming (McDonough & Fulga, 2015); explicit manipulations to make L2 speakers pay attention to syntax or notice the target form can also lead to greater priming (Shin & Christianson, 2012). Hence, previous research suggests that noticing the target structure and attention to the syntax or task can increase the magnitude of immediate priming.

However, there is little evidence as to whether these effects lead to increased learning via syntactic priming. Shin and Christianson (2012) found that explicit instructions provided to L2 speakers, which potentially increased attention to syntax or promoted noticing of the target structure, boosted immediate but not long-term priming on a delayed posttest. It may be that these instructions increased reliance on explicit memory of the prime sentences, leading to structure repetition across adjacent prime and target sentences but not long-term learning. Given that SLA findings suggest a clear role for attention in supporting L2 learning (Robinson et al., 2012), further research on the relationship between individual differences in attention and long-term priming is warranted. Moreover, whether modality has any influence on priming may be related to the (potential) effect of motivation and attention on syntactic priming. If, as argued, written language input facilitates syntactic processing for L2 speakers, then higher motivation and attention may be more helpful in the spoken modality, where processing prime sentences is more difficult. It may be more difficult for L2 speakers to pay attention to grammar when exposed to auditory L2 input as opposed to written L2 input (see Morgan-Short et al., 2012, for a review). Thus, being more attentive to the linguistic input may increase L2 priming, and consequently learning, more with spoken than with written prime sentences.

## The Present Study

The present study investigated the effects of prime modality and of individual differences in attention and motivation on L2 learning via syntactic priming. We compared immediate priming and learning from the spoken modality (listening-to-writing) to that from the written modality (reading-to-writing). We conceptualized learning as producing more target structures (namely,

passives) in posttests following a priming phase than in the pretest. We compared these effects in L2 speakers to those in L1 speakers in order to assess in what ways these variables particularly affect L2 speakers. Whereas attention can modulate priming in L1 speakers (e.g., Ivanova et al., 2020), modality may not (e.g., Mahowald et al., 2016). Therefore, to disentangle the relative contributions of speaker proficiency (L1 vs. L2) and attention to any effects of priming modality, we compared syntactic priming across modality conditions in both speaker groups and used questionnaires to assess their attention (L2 and L1 speakers) and their motivation (L2 speakers only).

We expected both groups to show immediate and long-term priming. However, whereas we predicted that L1 speakers would experience the same priming strength across modality conditions, we expected L2 speakers to exhibit more immediate priming, and consequently more learning, when reading than when listening to prime sentences. We predicted that being more attentive to syntax or task and noticing the target structure would increase immediate priming in both speaker groups, and we expected higher motivation levels to lead to greater immediate priming in L2 speakers. If this also leads to greater learning, it would indicate that priming mechanisms are susceptible to such variables. Finally, since we expected prime modality not to influence the priming magnitude in L1 speakers, we expected attention to have the same effect across modalities in that group. By contrast, we expected that attention and motivation would boost (at least immediate) priming more in the listening-to-writing than in the reading-to-writing condition in L2 speakers, as we anticipated that processing prime sentences would be more difficult in the former than in the latter condition for them.

We tested these predictions in a two-part web-based picture description task. We asked L1 French learners of L2 English and L1 English speakers to describe pictures of transitive events. The target structure was the passive transitive. Illustrated below are the active (1) and passive (2) transitive constructions of French and English. These constructions are highly similar across the two languages in terms of word order and morphosyntax. However, French speakers use the passive form less frequently both in French and in English than English speakers (Fivet, 1995), making it a suitable structure to assess whether priming supports language learning.

1. The pirate **is following** the sailor.
   *Le pirate **suit** le marin*.
2. The sailor **is being followed** by the pirate.
   *Le marin **est suivi** par le pirate*.

## Method

The first part of the study comprised a pretest, an immediate priming phase, and an immediate posttest. The second part was a delayed posttest completed at least a week after the first part. In the pretest, participants described pictures without exposure to syntactic primes; this measured their preference for active versus passive sentences. In the immediate priming phase, participants described target pictures immediately after listening to or reading prime picture descriptions. This phase targeted immediate priming effects. In the immediate and delayed posttests, participants described pictures without experiencing primes. These posttests measured whether priming effects established in the immediate priming phase persisted over time as short- and long-term learning. All study materials, including preregistration, are available via the Open Science Framework at https://osf.io/7mykb and https://osf.io/43efz.

### Participants

We tested 122 L2 learners and 123 L1 speakers, aged 17 to 28 years ($M$ = 19.77). The L2 learners were native French speakers and were all taking English classes, although none of them were majoring in English; their average length of learning was 11.58 years (*range* = 5–20). They were recruited via French universities and Prolific Academic (https://www.prolific.co), an online participant recruitment platform. A screening survey ensured that the learners recruited via Prolific Academic came from a similar demographic (in terms of language background, age range, and student status) to the other participants. They received reimbursement via Prolific Academic or as Amazon vouchers. The L1 speakers were first-year psychology students at the University of Warwick in the UK. They received course credit for their participation. The study was approved by the Humanities and Social Sciences Research Ethics Committee at the University of Warwick. All participants provided informed consent online before the test session.

We excluded one L2 speaker who wrote target sentences in French and one who provided active and passive versions of each target sentence. We excluded one L1 speaker who reported being a L1 speaker of both languages, three who produced only "other" sentences (see below), and one L2 and three L1 speakers due to technical issues (for further information, see https://osf.io/43efz). Therefore, the first part of the experiment (immediate priming and immediate posttest) included 119 L2 speakers (57 female) assigned between the listening (60) and the reading (59) condition, and 116 L1 speakers (102 female), also divided between the listening (56) and the reading (60) condition. For the second part of the experiment (delayed posttest), we excluded nine further participants

who completed the delayed posttest more than 10 days after the priming task (delay range: 11 days–2 months) and two participants who did not produce any transitive sentences. A further 12 participants did not attempt the delayed posttest. Thus, the analysis for long-term learning included 103 L2 speakers (listening condition: 54, reading condition: 49) and 109 L1 speakers (listening condition: 52, reading condition: 57). On average, L2 speakers completed the delayed posttest 7.6 days after the priming task, and L1 speakers 7.8 days.

We assessed L2 speakers' self-reported proficiency, which previous research has found to correlate with direct measures of proficiency (Lemhöfer & Broersma, 2012). Speakers rated their proficiencies in speaking, understanding spoken input, reading, and writing on a scale from 0 to 10, and we computed the average of these scores (Bernolet et al., 2013). L2 speakers had an average proficiency rating of 7.47 (*range* = 3.5–10). The two groups (listening vs. reading condition) did not differ significantly in any proficiency measurements (see Appendix S1 in the Supporting Information online).

## Materials

### *Prime and Target Pictures*

For the first part of the experiment, we created 36 target items using six verbs (*chase*, *follow*, *punch*, *scold*, *kiss*, *slap*) six times each with different combinations of animate agent and patient characters (based on stimuli from Hardy et al., 2017). Each target verb appeared once in the pretest (six items), four times in the priming phase (24 items), and once in the immediate posttest (six items). For the priming phase, we paired each target verb with one of six different verbs (*kick*, *push*, *touch*, *shoot*, *pull*, *tickle*), each of which was used four times with different combinations of characters to create 24 prime items that had no lexical overlap with the paired target items. Each prime item had an associated active and passive description (Figure 1). In the priming phase, prime–target pairs were separated by two filler pictures (resulting in a prime–target–filler–filler sequence); in the pretest and in the immediate posttest sections, target pictures were separated by three filler pictures. We created 84 filler pictures using intransitive verbs (represented with two characters: *the monks are crying*) and ditransitive verbs (represented with two characters and an object: *the monk is selling the artist a cup*); 18 were in the pretest, 48 in the priming phase, and 18 in the immediate posttest. For the delayed posttest, we created 12 additional target sentences using the six prime and six target verbs and 12 additional intransitive and ditransitive filler sentences, such that target sentences were separated by one filler sentence. We included word labels (articles, nouns, and verbs) in the target pictures in order to prevent problems of

vocabulary retrieval. The agent characters appeared an equal number of times on the right versus left side of the picture across pictures. For the listening condition, prime sentences were recorded by a female L1 English speaker who was instructed to read the stimuli as clearly and naturally as possible. We created two lists of stimuli so that one version of each experimental prime item (active or passive) would appear in each list in both the listening and reading conditions. Participants were randomly assigned to one list in one of the modality conditions.

*Picture–Sentence Matching Task*

To ensure that participants would pay attention to the prime sentences, we asked them to judge whether each prime sentence corresponded to the picture presented with it. We included three mismatches corresponding to filler trials in the pretest, 16 in the priming phase, and three in the posttest.

*Attention Questionnaire*

The attention questionnaire targeted three aspects of attention: attention to syntax, attention to the task, and noticing of target structures. First, participants provided a rating on a Likert scale (adapted from Takahashi, 2005) from 1 (*no attention/interest*) to 7 (*paid attention/very interested*) to indicate the extent to which they paid attention to and were interested in (1) the sentences they were exposed to during the task, (2) the picture description task in general, (3) the meaning, (4) the vocabulary, (5) the pronunciation, and (6) the syntactic structures of the sentences included in the syntactic priming task (responses to Questions 1, 2, and 6 only were used in the analysis). Second, we assessed participants' capacity to describe the syntactic rules and structures represented in the stimuli as evidence of their noticing of target structures (Brooks & Kempe, 2013; McDonough & Fulga, 2015) with three open-ended questions probing (1) what the experiment was about, (2) whether they noticed any grammatical rules underlying the sentences, and (3) whether they could name and/or describe what the rules were (for the full questionnaire, see https://osf.io/43efz).

*Motivation Questionnaire*

The motivation questionnaire targeted aspects of motivation that have previously been established as modulators of L2 achievement and production or that we hypothesized could influence syntactic priming. Some items came from existing, pretested questionnaires (Boekaerts, 2002; Deci & Ryan, 1985; Dörnyei & Taguchi, 2010; Saito et al., 2017; Serafini, 2013); others were created specifically for this study. It included items targeting externally

regulated motivation (eight items), intrinsic motivation (seven), task motivation (six), motivational intensity (six), how important learning English was for the participants (two), participants' metacognition about the task (five), and participants' language-learning goals (nine). Five items in the latter group specifically assessed whether participants were interested in improving their grammatical knowledge of English (grammar-learning goal). For a given question, participants were presented with one item of one of these motivation categories and asked to indicate on a Likert scale from 1 (*strongly disagree*) to 7 (*strongly agree*) to what extent they agreed with the statement. The presentation of items was randomized across categories and participants (for the full questionnaire, see https://osf.io/43efz).

## Procedure

Participants completed the study online in the survey programme Qualtrics (https://www.qualtrics.com). Upon clicking the link to the study, participants were randomly assigned by Qualtrics to the listening or reading condition. They first completed the consent form, followed by the proficiency questionnaire. The picture-description task then started with the pretest, where participants were shown a target picture and instructed to write a sentence describing it in a text response box below. The priming phase immediately followed the pretest. In the reading condition, the prime picture appeared with the prime sentence below it for 7 s. In the listening condition, the prime picture appeared for 7 s, and the recorded prime sentence played automatically when participants reached the page; they were instructed to listen to it only once. We constrained the time spent on this page in order to ensure that participants could only listen to the sentence once. Participants indicated whether the prime sentence corresponded to the presented picture and then were shown a target picture and instructed to write a description without any time constraint (Figure 1). Participants viewed prime and target pictures in alternation until all trials were completed; they then completed the immediate posttest, structured like the pretest. Throughout, participants judged whether filler sentences matched the presented picture by selecting one of two options, "yes" or "no," appearing below the picture as a multiple-choice question. Finally, participants filled in the motivation questionnaire (L2 speakers only), followed by the attention questionnaire (L2 and L1 speakers), providing answers on Likert scales or in response boxes. A week after completion of the first part of the study, all participants were invited to complete the delayed posttest, where they described target pictures as in the pretest and immediate posttest.

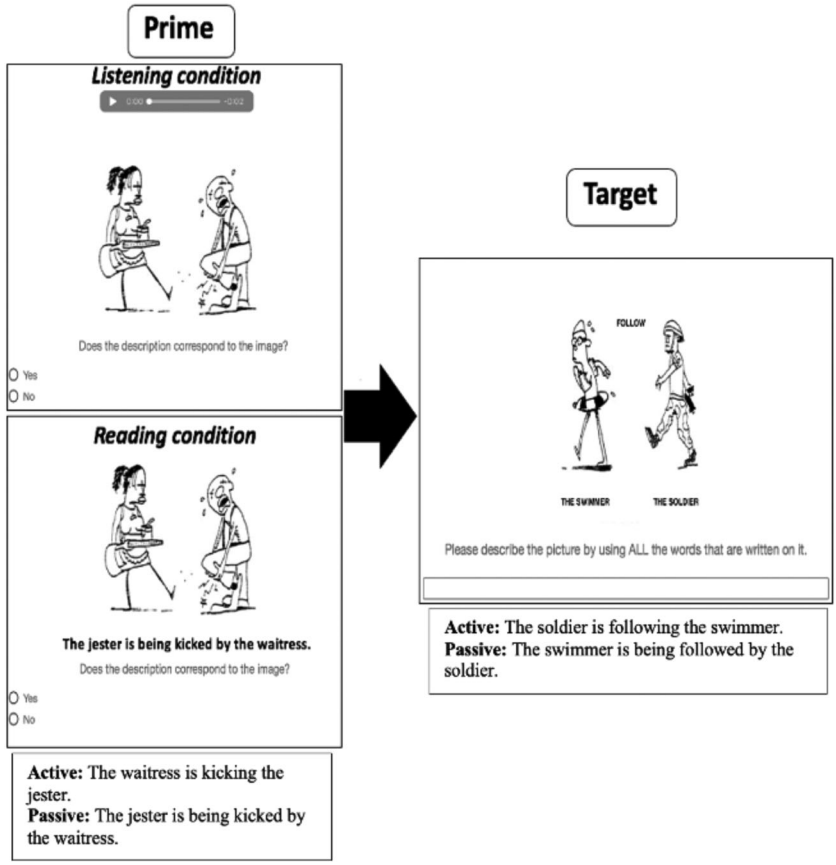


**Figure 1** Example of an experimental prime–target item. Each item appeared in the trial sequence: (1) experimental prime, (2) experimental target, (3) filler prime, (4) filler target.

## Data Analysis

### Scoring

*Target Sentences*

Target sentences were coded for whether they were active sentences, passive sentences, or "other." Complete active sentences contained a subject noun phrase referring to the agent, produced first, followed by the verb and, finally, an object noun phrase referring to the patient. Complete passive sentences contained a subject noun phrase referring to a patient, followed by a form of the verb *to be*, a past participle, and, finally, a *by*-phrase referring to an agent. We

ignored morphological errors, such as tense or agreement errors and naming errors in which participants used an alternative noun for a character (e.g., naming a character *the judge* instead of *the teacher*). We included sentences where one of the noun phrases was replaced by a pronoun or where two pronouns of distinct genders were produced, sentences with complex noun phrases (e.g., *the teacher kicked the clown's leg*), and sentences with an added auxiliary (e.g., *the waitress does kick the jester*) or with negation (e.g., *the fighter does not chase the robber*). All remaining responses, including reversed passives and actives (i.e., where the agent and patient roles were reversed) and active sentences that were not paraphrasable with a passive (e.g., with a modal auxiliary such as *the waitress can kick the jester*), were coded as "other" and excluded from the analyses.

*Attention Questionnaire*

We calculated three attention scores for each participant. To measure participants' overall attention to task, we averaged their scores for Questions 1 (attention to sentences) and 2 (attention to task) of the attention questionnaire.[1] We used their rating for Question 6 to assess their attention to syntax. Participants' responses to the open-ended questions were scored so as to distinguish noticing from noticing and understanding (Schmidt, 1990). Participants received a score of 2 (henceforth Noticing 2) if they indicated they had noticed and understood the alternations, that is, they were able to name, describe, or give examples of the passive/active sentences. They received a score of 1, which corresponded to noticing only (henceforth Noticing 1), if they mentioned some aspect of the passive, such as the use of past participles or past tense, or "indirect versus direct form" to describe the actions, or that who was doing what to whom mattered. They received a score of 0 if they did not refer to the passive/active alternation or its features in any way.

*Motivation Questionnaire*

We conducted a principal components analysis of the L2 speakers' scores on the 43 Likert-scale survey items in order to identify correlated responses across the different categories of motivation and reduce the number of motivation dimensions. The analysis revealed that two principal components (PC1, PC2) accounted for the most variance in the data, with PC1 explaining 17.7% of variance (Cronbach's alpha .88) and PC2 explaining 9.4% (Cronbach's alpha .80); the remaining components accounted for only 5% or less variance. We selected the items loading on PC1 and PC2, and avoided cross-loadings, by following Takahashi's (2005) cut-off criterion of .45 correlation level. The

final two motivation scores we included in the analysis corresponded to PC1 and PC2 and were calculated by averaging an individual's scores across all the items, loading on each respectively. PC1 included all items measuring how important it was for participants to learn English (two items); six of the seven items from the original intrinsic motivation category; six of the nine items from the learning goal category, of which three specifically targeted grammar learning; four of the six items from the motivational intensity category; and one of the eight items from the external motivation category. PC2 included four of the five items from the metacognition category and four of the six items from the task motivation category. We interpreted PC1 as representing motivation to learn English and PC2 as representing task-specific motivation (for detailed results, see https://osf.io/43efz).

**Statistical Modeling**

We compared priming effects across modality conditions and speaker groups over the three different time courses: immediate priming, short-term learning, and long-term learning. Then, we explored the effects of individual differences on each priming type in each modality condition.

*Priming Across Modality Conditions*

We analyzed the effect of priming on passive responses, as participants dispreferred passives in the pretest. Since our dependent variable was binary, coded as 0 = active and 1 = passive, we analyzed the data with generalized logistic mixed models (Baayen et al., 2008; Jaeger, 2008), using the lme4 package (Version 1.1.21; Bates et al., 2014) in R, Version 1.2.5042. The categorical predictors were sum contrast coded to have a mean of 0 and a range of 1 prior to analysis. The between-participants variables were modality (listening, −.5, vs. reading, .5) and group (L1 speakers, −.5, vs. L2 speakers, .5). The within-participants variables were prime (active primes, −.5, vs. passive primes, .5) for immediate priming, section (pretest, −.5, vs. immediate posttest, .5) for short-term learning, or session (pretest, −.5, vs. delayed posttest, .5) for long-term learning.

All analyses started with a full model including main effects and interactions and the maximal by-subject and by-item random effects structure justified by our experimental design (Barr et al., 2013). All models included random intercepts for participants and items, by-subject random slopes for within-participant variables (prime, section, session), and by-item random slopes for within-item variables (prime, group, modality) and their interactions. Where models did not converge, we removed random slopes and

interactions before main effects, starting with those accounting for the least variance. Then, we performed a stepwise best-path reduction procedure, removing interactions before main effects, to locate the simplest (best) model that did not differ significantly from the full (converging) model in terms of variance explained but did differ significantly from a null model with only the intercept term as a predictor. We report the results of the best models with all *p* values for individual predictors coming from the model summary outputs. We applied an alpha level of .05, but when splitting datasets to explore significant interactions, we applied Bonferroni correction with a corrected alpha level of .025.

Since the interactions between priming, modality, and group were critical to our research questions, in the case of nonsignificant results, we used the Bayesian information criterion (BIC) values of the models to estimate the Bayes factor (BF) as $e^{(\text{AlternativeBIC}-\text{NullBIC})/2}$ and quantify the likelihood of null effects. Following Wagenmakers (2007), we compared a model with only the main effects of the variables (null model) to a model that contained the three-way interaction between these variables (alternative model). We interpreted inverse BFs following Jarosz and Wiley's (2014) suggestions and effect sizes based on Cohen's (1977) guidelines.

*The Effect of Individual Differences*

We examined the effect of individual differences in attention and motivation across modality conditions on each priming type. For attention, we separately added each individual difference measure and its interactions with the other variables as fixed effects to the best models obtained in the first part of the analysis.[2] For motivation, since the analysis only included the L2 speakers, we started with a full model of the L2 priming data only, including all the required fixed and random effects for each priming type. Continuous predictors (attention to syntax, attention to task, English-learning motivation, and task-specific motivation) were centered, with the exception of proficiency, which had a scale starting at a meaningful 0. Noticing was defined as a categorical variable with three levels, where 0 = not noticing the target structure, 1 = noticing it (Noticing 1), and 2 = noticing and understanding it (Noticing 2). This variable was sum contrast coded, where we used multiple contrasts to first compare not noticing (−.66) to any level of noticing, that is, to Noticing 1 (.33) and Noticing 2 (0.33) combined, and then to compare the different levels of noticing, Noticing 1 (−.5) and Noticing 2 (.5). Following Weatherholtz et al. (2014), we compared each model that included the targeted individual differences score to the same model without the score (henceforth, the

**Table 1** Frequency of target responses by group, modality, and experiment phase for immediate priming and short-term learning

| | | | Response | | |
|---|---|---|---|---|---|
| Group | Condition | Phase (prime) | Active | Passive | Other |
| L2 | Listening | Pretest | 315 | 6 | 39 |
| | ($n = 60$) | Priming (active) | 609 | 80 | 31 |
| | | Priming (passive) | 490 | 195 | 35 |
| | | Immediate posttest | 299 | 47 | 14 |
| | Reading | Pretest | 310 | 4 | 40 |
| | ($n = 59$) | Priming (active) | 585 | 83 | 40 |
| | | Priming (passive) | 523 | 140 | 45 |
| | | Immediate posttest | 287 | 56 | 11 |
| L1 | Listening | Pretest | 255 | 5 | 76 |
| | ($n = 56$) | Priming (active) | 595 | 13 | 64 |
| | | Priming (passive) | 517 | 89 | 66 |
| | | Immediate posttest | 304 | 9 | 23 |
| | Reading | Pretest | 289 | 6 | 65 |
| | ($n = 60$) | Priming (active) | 587 | 33 | 100 |
| | | Priming (passive) | 531 | 88 | 101 |
| | | Immediate posttest | 290 | 23 | 47 |

simplest model). We report the results of the models that provided a better fit than the simplest model.

## Results

### Descriptive Statistics

Table 1 reports participants' response frequencies in the immediate priming phase and immediate posttest; Table 2 reports response frequencies in the delayed posttest (from which some participants' data were excluded, as described previously). The pretest confirmed that participants preferred to use active responses, but overall, participants did produce more passives following priming.

All participants performed above chance level (50% correct answers or 11/22) on the picture–sentence matching task. As summarized in Table 3, L2 speakers made 1.43 mistakes on average (*range* = 0–12), and L1 speakers made a mean of 1.19 mistakes (*range* = 0–12). For attention to task, L2 speakers showed a mean score of 5.22 (*range* = 1–7), and L1 speakers showed a mean score of 4.72 (*range* = 1–7); for attention to syntax, L2 speakers showed a mean score of 5.03 (range 2–7), while L1 speakers showed a mean score

**Table 2** Frequency of target responses by group, modality, and experiment phase for long-term learning

| | | | Response | | |
|---|---|---|---|---|---|
| Group | Condition | Phase | Active | Passive | Other |
| L2 | Listening | Pretest | 282 | 6 | 36 |
| | ($n = 54$) | Delayed posttest | 517 | 111 | 20 |
| | Reading | Pretest | 259 | 4 | 33 |
| | ($n = 49$) | Delayed posttest | 473 | 85 | 30 |
| L1 | Listening | Pretest | 240 | 3 | 69 |
| | ($n = 52$) | Delayed posttest | 543 | 28 | 53 |
| | Reading | Pretest | 279 | 6 | 57 |
| | ($n = 57$) | Delayed posttest | 590 | 30 | 64 |

**Table 3** Descriptive statistics for individual differences, showing mean scores, standard deviations, and ranges by group and modality

| | L2 | | L1 | |
|---|---|---|---|---|
| Measure | Listening | Reading | Listening | Reading |
| Attention – Syntax | 5.18 (1.19), 2–7 | 4.86 (1.19), 2–7 | 4.75 (1.64), 1–7 | 4.43 (1.65), 1–7 |
| Attention – Task | 5.09 (1.23), 1–7 | 5.32 (1.04), 3–7 | 4.95 (1.09), 1–7 | 4.5 (1.04), 2–6.5 |
| English-learning motivation (PC1) | 5.66 (0.66), 3.20–6.85 | 4.49 (0.58), 2.65–5.45 | | |
| Task-specific motivation (PC2) | 3.70 (1.10), 1.13–5.63 | 3.72 (0.67), 2.00–5.88 | | |
| *N* picture–sentence matching mistakes | 1.13 (2.44), 0–6 | 1.73 (2.51), 0–12 | 0.77 (1.21), 0–7 | 1.58 (2.26), 0–12 |

*Note*. Standard deviations are presented in parentheses, followed by ranges. L2 = second language; L1 = first language; PC1 = Principal Component 1; PC2 = Principal Component 2.

of 4.59 (*range* = 1–7). L2 speakers had an average rating of 5.08 (*range* = 2.65–6.85) for English-learning motivation and 3.71 (*range* = 1.13–5.88) for task-specific motivation. Regarding noticing, as reported in Table 4, 45.4% of L2 speakers scored 2, 14.3% scored 1, and 40.3% scored 0; 14.7% of L1 speakers scored 2, 9.5% scored 1, and 75.9% scored 0.

**Table 4** Noticing statistics, showing raw number and percentage (in parentheses) of participants per group and condition whose responses were scored 0, 1, and 2

| | L2 | | L1 | |
|---|---|---|---|---|
| Noticing score | Listening | Reading | Listening | Reading |
| 0 | 24 (40%) | 24 (40.7%) | 40 (71.4%) | 48 (80%) |
| 1 | 9 (15%) | 8 (13.6%) | 6 (10.7%) | 5 (8.3%) |
| 2 | 27 (45%) | 27 (45.8%) | 10 (17.9%) | 7 (11.7%) |

*Note*. L2 = second language; L1 = first language.

**Table 5** Summary of the best model for immediate priming of passives across groups and modalities

| Fixed effects | Estimate | 95% CI | *SE* | *z* | *p* |
|---|---|---|---|---|---|
| Intercept | −3.30 | [−3.70, −2.90] | 0.20 | −16.18 | < .001 |
| Prime | 1.58 | [0.99, 2.17] | 0.30 | 5.21 | < .001 |
| Group | 1.40 | [0.78, 2.02] | 0.32 | 4.44 | < .001 |
| Modality | 0.10 | [−0.45, 0.66] | 0.28 | 0.36 | .719 |
| Prime × Group | −0.53 | [−1.34, 0.29] | 0.42 | −1.27 | .205 |
| Prime × Modality | −0.80 | [−1.60, −0.01] | 0.41 | −1.97 | .048 |
| Group × Modality | −0.79 | [−1.91, 0.32] | 0.57 | −1.40 | .161 |
| Prime × Group × Modality | 0.27 | [−1.32, 1.86] | 0.81 | 0.33 | .739 |

*Note*. The model included by-subject random slopes for prime and by-item random slopes for group.

## Second Versus First Language Immediate Priming and Learning in the Listening and Reading Conditions

### *Immediate Priming*

We investigated the effect of modality on immediate priming across groups with a model including prime, modality, group, and the three-way interaction as fixed effects (Table 5). We found a significant effect of prime. Participants produced more passive targets after passive primes ($M = 0.20$, $SD = 0.40$, 95% CI [0.18, 0.21]) than after active primes ($M = 0.08$, $SD = 0.27$, 95% CI [0.07, 0.09]), with a priming effect of 12% (95% CI [8, 15], Cohen's $d = 0.54$, $SE = 0.02$, corresponding to a medium effect). There was a significant effect of group. L2 speakers produced more passives ($M = 0.18$, $SD = 0.39$, 95% CI [0.17, 0.20]) than L1 speakers ($M = 0.09$, $SD = 0.29$, 95% CI

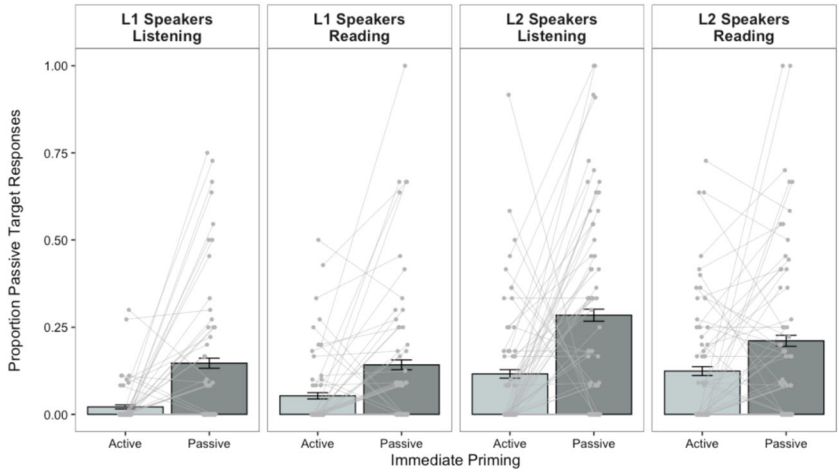


**Figure 2** Passive responses in the immediate priming phase. Mean proportion of passive responses by prime, modality, and group. Error bars indicate the standard error of the mean, grey dots individual data points, and grey lines individual priming effects. L1 = first language; L2 = second language.

[0.08, 0.10]). Finally, we found a significant interaction between prime and modality. Participants experienced 14.8% priming in the listening condition (95% CI [9, 20], Cohen's $d = 0.68$, $SE = 0.03$, corresponding to a medium-to-large effect), whereas they experienced 8.8% priming in the reading condition (95% CI [4, 13], Cohen's $d = 0.40$, $SE = 0.02$, corresponding to a medium effect). The interaction between prime, modality, and group was not significant; the inverse BF value of .0003 provided very strong evidence (Jarosz & Wiley, 2014) in favor of the null hypothesis. Thus, participants manifested greater priming when listening to than when reading primes, but this effect did not vary by group (Figure 2).

*Short-Term Learning*

We analyzed the effect of modality on short-term learning across groups with a model including section, modality, group, and the three-way interaction as fixed effects (Table 6). We found a significant effect of section. Participants produced more passives in the immediate posttest ($M = 0.10$, $SD = 0.30$, 95% CI [0.09, 0.12]) than in the pretest ($M = 0.02$, $SD = 0.13$, 95% CI [0.01, 0.03]), with an average increase of 8% (95% CI [6, 11], Cohen's $d = 0.57$, $SE = 0.01$, corresponding to a medium effect). The three-way interaction

**Table 6** Summary of the best model for short-term learning of passives across groups and modalities

| Fixed effects | Estimate | 95% CI | *SE* | *z* | *p* |
|---|---|---|---|---|---|
| Intercept | −6.77 | [−7.97, −5.57] | 0.61 | −11.04 | < .001 |
| Section | 5.81 | [3.46, 8.15] | 1.20 | 4.85 | < .001 |
| Group | 0.73 | [−0.52, 1.98] | 0.64 | 1.14 | .254 |
| Modality | 0.27 | [−0.98, 1.51] | 0.63 | 0.42 | .672 |
| Section × Group | 2.05 | [−0.37, 4.46] | 1.23 | 1.66 | .097 |
| Section × Modality | 0.91 | [−1.50, 3.31] | 1.23 | 0.74 | .461 |
| Group × Modality | −0.73 | [−3.21, 1.76] | 1.27 | −0.57 | .567 |
| Section × Group × Modality | −0.27 | [−5.09, 4.54] | 2.46 | −0.11 | .911 |

*Note*. The model included by-subject random slopes for section.

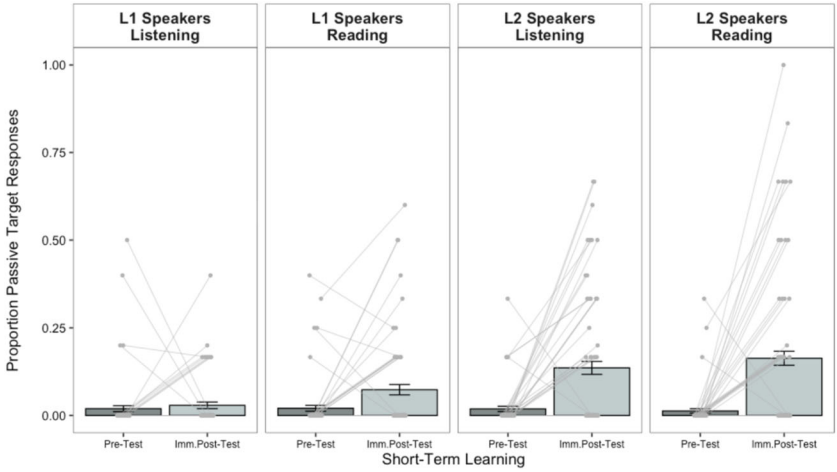


**Figure 3** Passive responses in the pretests and immediate posttests. Mean proportion of passive responses by section, modality, and group. Error bars indicate the standard error of the mean, grey dots individual data points, and grey lines individual priming effects. L1 = first language; L2 = second language; imm. = immediate.

between section, modality, and group was not significant; the inverse BF value of < .0067 provided very strong evidence (Jarosz & Wiley, 2014) in favor of the null hypothesis. Therefore, participants experienced learning, but neither prime modality nor group influenced the magnitude of this learning (Figure 3).

**Table 7** Summary of the best model for long-term learning of passives across groups and modalities

| Fixed effects | Estimate | 95% CI | *SE* | *z* | *p* |
|---|---|---|---|---|---|
| Intercept | −5.67 | [−6.60, −4.74] | 0.47 | −11.95 | < .001 |
| Session | 2.26 | [1.44, 3.09] | 0.42 | 5.40 | < .001 |
| Group | 1.35 | [0.27, 2.42] | 0.55 | 2.46 | .014 |
| Modality | −0.05 | [−1.11, 1.00] | 0.54 | −0.09 | .925 |
| Session × Group | 1.68 | [0.59, 2.77] | 0.56 | 3.01 | .003 |
| Session × Modality | −0.07 | [−1.15, 1.01] | 0.55 | −0.13 | .899 |
| Group × Modality | −0.92 | [−2.83, 1.00] | 0.98 | −0.94 | .349 |

*Note*. The model included two-way interactions between the variables only and no random slopes.

*Long-Term Learning*

We examined the effect of modality on long-term learning across groups with a model including session, modality, group, and the three-way interaction as fixed effects (Table 7). We found a significant effect of session. Participants produced more passive sentences in the delayed posttest ($M = 0.11$, $SD = 0.31$, 95% CI [0.09, 0.12]) than in the pretest ($M = 0.02$, $SD = 0.13$, 95% CI [0.01, 0.03]), indicating an average long-term priming effect of 9% (95% CI [6, 12], Cohen's $d = 0.57$, $SE = 0.01$, corresponding to a medium effect). There was a significant effect of group. L2 speakers produced more passive sentences overall ($M = 0.12$, $SD = 0.32$, 95% CI [0.10, 0.13]) than L1 speakers ($M = 0.04$, $SD = 0.19$, 95% CI [0.03, 0.05]). There was no significant three-way interaction between session, modality, and group, with the inverse BF value of .02 providing strong evidence in favour of the null hypothesis (Jarosz & Wiley, 2014). However, there was a significant interaction between session and group. Further exploration with the data split by group revealed that both L2 and L1 speakers experienced a significant effect of session. L2 speakers produced more passives in the delayed posttest ($M = 0.17$, $SD = 0.37$) than in the pretest ($M = 0.02$, $SD = 0.13$; $b = 3.16$, 95% CI [2.06, 4.27], $SE = 0.57$, $z = 5.60$, $p < .001$), as did L1 speakers who provided more passives in the delayed posttest ($M = 0.05$, $SD = 0.22$) than in the pretest ($M = 0.02$, $SD = 0.13$; $b = 1.50$, 95% CI [0.61, 2.39], $SE = 0.45$, $z = 3.31$, $p = .001$). However, this long-term priming effect was larger in L2 speakers (15%, 95% CI [11, 20], Cohen's $d = 0.82$, $SE = 0.02$, corresponding to a large effect) than in L1 speakers (3%, 95% CI [0, 6], Cohen's $d = 0.26$, $SE = 0.01$, corresponding to a small-to-medium effect). Thus, L2 speakers showed greater long-term

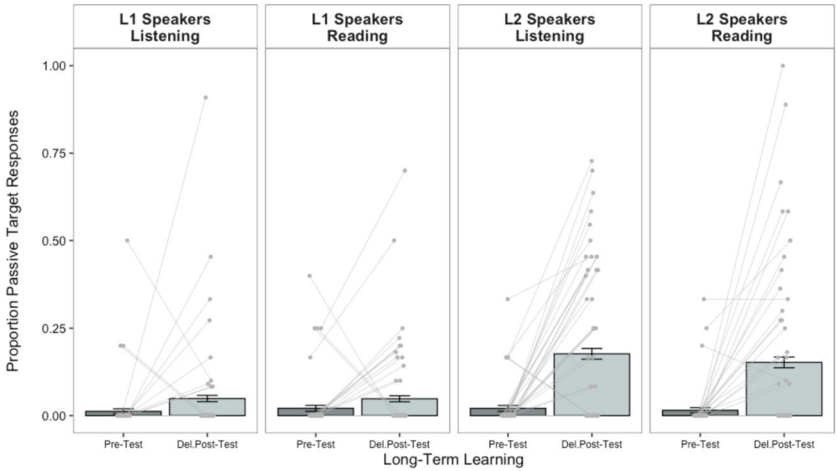


**Figure 4** Passive responses in the pretests and delayed posttests. Mean proportion of passive responses by session, modality, and group. Error bars indicate the standard error of the mean, grey dots individual data points, and grey lines individual priming effects. L1 = first language; L2 = second language; del. = delayed.

learning than L1 speakers, but there was no effect of modality (Figure 4). In sum, both L2 and L1 speakers showed immediate and lasting priming effects, but long-term learning was greater in L2 than in L1 speakers. Immediate priming was stronger in the listening than in the reading group, but prime modality did not affect lasting priming effects.

### Effects of Individual Differences

We first examined whether proficiency related to syntactic priming in L2 speakers in order to determine whether to include it as a covariable in each model. The converging models showed that proficiency did not relate to immediate priming ($p > .09$), short-term learning ($p > .26$), or long-term learning ($p > .20$). Thus, we did not include it in any of the models exploring individual differences. The models that included attention to syntax, attention to task, English-learning motivation, and task-specific motivation did not significantly differ from the simplest models for immediate priming ($p > .28$), short-term learning ($p > .13$), or long-term learning ($p > .39$). Although the converging model for noticing did significantly differ from the simplest models for all three priming analyses ($p < .05$), no analyses revealed a significant effect of noticing ($p > .11$; see Appendix S2 in the Supporting Information online for details). Thus overall, individual differences in

attention and motivation did not significantly relate to any of the three priming types.

## Discussion

We investigated the effects of prime modality—that is, reading versus listening to prime sentences—on L2 learning via syntactic priming and examined how this related to individual differences in attention and motivation. Both L2 and L1 speakers experienced immediate priming, short-term learning, and long-term learning. Interestingly, L2 speakers produced more passives than L1 speakers in the immediate priming phase and showed greater long-term learning than L1 speakers when tested a week later. Participants across speaker groups experienced more immediate priming when listening to than when reading primes, but prime modality did not affect short-term or long-term learning in either group. Finally, individual differences in attention and motivation did not modulate priming effects. We discuss the implications of these results for models of syntactic priming and L2 learning.

### Syntactic Priming Effects

As per the predictions of the models defining syntactic priming as a language-learning mechanism (e.g., Chang et al., 2006; Reitter et al., 2011), both groups exhibited immediate priming and learning in the immediate and delayed posttests, respectively (cf. Grüter et al., 2021; McDonough & Chaikitmongkol, 2010). Overall, the L2 speakers produced more passives than L1 speakers in the immediate priming phase. Since both groups produced very few passives in the pretest, this greater increase for the L2 speakers implies that the passive primes affected them more than they affected the L1 speakers. The L2 speakers may have used prime sentences as models for nativelike language production and decided to reuse their structure to formulate sentences; learners may choose such a strategy to improve their L2 skills (Costa et al., 2008). However, this explanation is difficult to reconcile with the observation that noticing did not affect priming and that the L2 speakers also experienced greater long-term priming than the L1 speakers in the delayed posttest. Explicit processes, such as copying the structure of prime sentences based on explicit memories, are thought to have a short-lived influence on priming effects (e.g., Hartsuiker et al., 2008).

Rather, these results may corroborate key predictions of the language-learning models of priming. The error-based mechanism of priming predicts that L2 speakers, who have less experience with the target language, should be more likely to experience prediction error and therefore more syntactic priming

and learning than L1 speakers (Chang et al., 2006). Alternatively, given their inexperience, L2 speakers' syntactic representations should have lower base-level activation, which should lead to increased production and more learning than representations with higher base-level activation (Reitter et al., 2011; but see Schoonbaert et al., 2007). L1 speakers have more entrenched knowledge of the target structure and its associated frequency, and as a result may need more exposure to passives for their normal biases to be affected in the long term. Importantly, not only did the L2 speakers produce more passives than the L1 speakers in the immediate priming phase, but they also showed greater long-term priming than the L1 speakers. Such results strongly support the predictions of the language-learning models of priming (Chang et al., 2006; Reitter et al., 2011) that priming manipulations should affect L2 speakers more than L1 speakers, both in immediate and long-term priming contexts.

We did not, however, find any difference between speaker groups in short-term learning effects, as measured by the immediate posttest. One possibility is that L1 and L2 speakers differed in the degree of long-term effects, but not short-term learning, because of differences in exposure to English between sessions. The L1 speakers were based in the United Kingdom and would have had such exposure, which could have reduced the long-term effect of priming in this group; in contrast, most L2 speakers were living in France when tested and such exposure would thus have been less likely for them. However, this would not explain why greater immediate priming in learners did not lead to greater short-term learning. Further, the numerical results, if not the statistical results, seem incompatible with this explanation. For example, Figure 3 shows greater short-term learning for L2 speakers than L1 speakers, a similar result to that for long-term learning (Figure 4). An alternative possibility is that there were fewer items in the immediate posttest (six) than in the delayed posttest (12), which may have reduced the discriminability of the immediate posttest. Given the inherent difficulties of interpreting a null result, the reason for this lack of difference in the immediate posttest remains unclear.

The significant learning observed suggests that the effects of priming were nonetheless lasting across groups. Thus, the results provide strong evidence that syntactic priming tasks help L2 learners strengthen syntactic representations of dispreferred structures for immediate and delayed reuse. This indicates that L2 (and L1) speakers' syntactic preferences can be shifted durably, and that knowledge acquired during the priming task can be reused across sessions without reexposure to prime sentences (McDonough & Chaikitmongkol, 2010).

**The Effect of Prime Modality**

Participants across groups experienced more immediate priming in the listening than in the reading condition. This contradicts our predictions and previous research reporting no effect of modality on L1 priming (Hartsuiker et al., 2008; Mahowald et al., 2016) or larger L2 priming in written than in oral interactions (Y. Kim et al., 2019, 2020). Our pattern of results is, however, compatible with findings that auditory input leads to better recall overall (Zhao et al., 2021), as suggested by studies showing that auditory stimuli foster better learning than visual stimuli (e.g., Frost et al., 2019; Zhao et al., 2021).

Alternatively, this could indicate that the participants experienced inverse frequency effects, another prediction of the language-learning models of priming (Chang et al., 2006; Reitter et al., 2011). The passive structure tends to be more common in written than in spoken language (Roland et al., 2007). Therefore, the participants in the listening condition may have experienced larger surprisal and hence larger prediction error (Chang et al., 2006) or larger increases in base-level activation (Reitter et al., 2011), triggering greater priming, as a result of their exposure to passives in this modality, compared to participants in the reading condition. That is, although syntactic representations are typically assumed to be amodal, this study may provide preliminary evidence that syntactic representations are stored with contextual information regarding their frequency of use in different modalities (Jaeger & Snider, 2013), such that speakers are more likely to predict a passive in written than in spoken language. That modality affected priming to the same extent across speaker groups could indicate that the L2 speakers had the same knowledge as the L1 speakers of the frequency of passives in the spoken versus the written modality in English. Future researchers should examine the effect of modality in priming when targeting structures that occur with the same frequency across modalities, in order to further assess the effect of this variable on priming and learning.

However, contrary to our expectations, this effect of modality did not extend to the posttest phases. Greater immediate priming in the listening condition did not translate into greater long-term priming compared to the reading condition. This suggests that the effect of modality was short-lived. This is surprising since, across speaker groups, we observed that greater immediate effects of priming led to greater long-term effects. Such a null effect is difficult to interpret, and therefore further research is needed to explore this pattern of results.

Since participants experienced significant priming and learning across modalities, the results demonstrate further that L2 speakers can reuse

syntactic knowledge regardless of the input modality of the target structures (K. M. Kim & Godfroid, 2019). They also show that priming and learning arise within modalities (reading-to-writing) and between modalities (listening-to-writing) in L2 speakers (K. M. Kim & Godfroid, 2019), thereby suggesting that, at higher proficiency levels at least, syntactic representations are shared across modalities.

**The Effects of Attention and Motivation**

We expected attention to linguistic input across speaker groups and enhanced motivation levels in L2 speakers to increase immediate priming (e.g., Bock et al., 1992; Ivanova et al., 2020; McDonough & Fulga, 2015; Ushioda, 2016), and to be more likely to do so in the listening than in the reading condition. The possible long-term effects of these variables were less clear (e.g., Shin & Christianson, 2012). However, attention and motivation did not relate to short- or long-term priming. Neither noticing the target structure nor being highly motivated or attentive to the syntax or to task increased immediate priming or language learning via syntactic priming across speaker groups. These results may suggest that for L1 and L2 speakers, syntactic priming is an implicit language processing and learning mechanism that remains insensitive to explicit processes such as attention and motivation.

However, our results concerning attention contrast with previous findings whereby higher attention to syntax and to task or noticing the target structure triggered larger immediate syntactic priming effects (e.g., Bock et al., 1992; Ivanova et al., 2020; McDonough & Fulga, 2015). This discrepancy may result from methodological differences between our study and past work. In previous studies reporting an effect of attention on immediate priming, the activities took place entirely in the oral modality, that is, participants heard prime sentences, sometimes repeated them, and produced spoken target sentences. Noticing or paying more attention to the task or target structures may influence oral production more than written production. When writing sentences, participants may be more likely to rely on their default preferred structure even when attention levels are higher because, for instance, typing active rather than passive sentences is less effortful or quicker (Y. Kim et al., 2020). Our measurements of attention to task and syntax may also have been not perfectly accurate in measuring individual differences in attention, as we only used explicit and subjective self-report questionnaires. Such self-reports could reflect participants' memory for the target structure or other aspects of the task.

Moreover, although we considered the passive construction to be sufficiently infrequent and difficult to pose a challenge for learners to spontaneously

produce, attention and motivation may not have influenced L2 priming in our study because being attentive or motivated is more helpful in learning more complex structures (Carr & Curran, 1994; Takahashi, 2005), such as object relative clauses (e.g., *Sara saw the puppy that she liked*). Alternatively, these variables may play a larger role with target structures that do not exist in the learners' L1, unlike English passives as targets for French L1 speakers, given the high degree of similarity between English and French passives. Targeting structures for which learners cannot rely on crosslinguistic transfer for processing might lead them to benefit more from deeper processing triggered by high attention and motivation levels. Further across-structure comparisons are needed to test these hypotheses. Finally, SLA research typically examines the effect of motivation on overall L2 abilities (Ushioda, 2016), but motivation may not relate to the learning of specific linguistic features, as promoted in syntactic priming tasks.

## Limitations and Future Directions

Given the potential difficulties with subjective self-report questionnaires as used in this study, future research may better assess the effect of attention on priming by directly manipulating what participants need to pay attention to during the priming task (Bock et al., 1992), or by directly quantifying variation in attention with implicit methods, such as eye-tracking (Michel & Smith, 2018), or with measurements such as reaction times (Ivanova et al., 2020). Motivation could similarly be directly manipulated by comparing priming across conditions that are more or less likely to foster high levels of task-specific motivation, such as whether participants receive a reward or not. Finally, variables such as modality and individual differences in attention and motivation may be more relevant to language processing and learning in less proficient L2 speakers. Reading primes may facilitate learning more than listening to them in less proficient learners, who may have difficulties understanding L2 pronunciation or computing syntax online. Future researchers could recruit beginner learners in order to further elucidate how these variables affect L2 learning via syntactic priming.

## Conclusion

This study shows that syntactic priming tasks support the long-term learning of L2 syntactic knowledge. Although this occurs regardless of prime modality, L2 and L1 speakers' immediate priming magnitude may vary depending on the frequency of the target structure in each modality. These results, combined with the greater production of passives and greater learning magnitudes

in L2 than in L1 speakers, provide support for the mechanisms proposed in the language-learning models of syntactic priming (Chang et al., 2006; Reitter et al., 2011). Finally, syntactic priming and the resultant learning seem unaffected by individual differences in attention and motivation. Further research is required to investigate the impact of language input modality and individual differences on such learning of other structures and in learners with lower levels of proficiency, for whom these variables may be more critical.

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## Notes

1 The scores for Questions 1 and 2 of the attention questionnaire were significantly correlated ($p < .001$).
2 An additional analysis with attention scores added to the full models instead showed the same results as described below.

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## Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

**Accessible Summary**

**Appendix S1.** Language Background Information.

**Appendix S2.** Additional Analyses for Individual Differences.

**Appendix S3.** Analyses Without Outliers.