



## Lexically-specific syntactic restrictions in second-language speakers

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### ABSTRACT

In two structural priming experiments, we investigated the representations of lexically-specific syntactic restrictions of English verbs for highly proficient and immersed second language (L2) speakers of English. We considered the interplay of two possible mechanisms: generalization from the first language (L1) and statistical learning within the L2 (both of abstract structure and of lexically-specific information). In both experiments, L2 speakers with either Germanic or Romance languages as L1 were primed to produce dispreferred double-object structures involving non-alternating dative verbs. Priming occurred from ungrammatical double-object primes involving different non-alternating verbs (Experiment 1) and from grammatical primes involving alternating verbs (Experiment 2), supporting abstract statistical learning within the L2. However, we found no differences between L1-Germanic speakers (who have the double-object structure in their L1) and L1-Romance speakers (who do not), inconsistent with the prediction for between-group differences of the L1-generalization account. Additionally, L2 speakers in Experiment 2 showed a lexical boost: There was stronger priming after (dispreferred) non-alternating same-verb double-object primes than after (grammatical) alternating different-verb primes. Such lexically-driven persistence was also shown by L1 English speakers (Ivanova, Pickering, McLean, Costa, & Branigan, 2012) and may underlie statistical learning of lexically-dependent structural regularities. We conclude that lexically-specific syntactic restrictions in highly proficient and immersed L2 speakers are shaped by statistical learning (both abstract and lexically-specific) within the L2, but not by generalization from the L1.

### Introduction

Most first-language (L1) speakers of English would agree that a sentence such as *The widow donated the church the money* does not sound quite right. This is because some verbs of transfer such as *give* are used with both a prepositional-object (e.g., *The widow gives the money to the church*) and a double-object structure (e.g., *The widow gives the church the money*), while other verbs of transfer such as *donate* are used primarily with the prepositional-object structure. However, second-language (L2) learners of English are not typically taught these distinctions (e.g., Juffs, 1998).

What factors guide how highly-proficient L2 speakers immersed in the L2 environment represent such fine-grained lexically-specific syntactic restrictions? They could do so by *generalization* from the behavior of verbs' translations in their L1, by developing knowledge of the

relevant restrictions from exposure to the behavior of these verbs directly in their L2 (*statistical learning*), or by a combination thereof (as has been shown for L1 acquisition: Ambridge, Pine, Rowland, & Chang, 2012; Ambridge, Pine, Rowland, Freudenthal, & Chang, 2014). In this study, we investigate the role of these factors in two structural priming experiments using the dative alternation in English, with two groups of highly-proficient L2 speakers of English who are L1-Germanic and L1-Romance speakers.

The dative alternation is a lexically-specific syntactic restriction in English. As mentioned above, some dative verbs (such as *give*, *send*, *show*, *offer*) are used in both the prepositional-object (1a) and double-object structures (1b) and are known as *alternating*. Other dative verbs (such as *donate*, *return*, or *recommend*) are used with the prepositional object (2a) in the vast majority of cases and are known as *non-alternating*.

1a. The monk gives the book to the boy (alternating, prepositional

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object).

1b. The monk gives the boy the book (alternating, double object).

2a. The monk donates the book to the boy (non-alternating, prepositional object).

2b. ?The monk donates the boy the book (non-alternating, double object).

Of note, such verbs do occur with the double-object structure, albeit rarely, as in (2b). The use of non-alternating verbs in double object utterances is more likely in spoken production, when the recipient is denoted by a pronoun<sup>1</sup> (e.g., *Please convey him my sympathies*), and when the theme is “heavy” (longer and/or structurally more complex, e.g., *I’m returning you the book I borrowed last week*).<sup>2</sup> These observations are supported by corpora studies showing a number of factors that affect structural preferences in terms of prepositional and double objects in ditransitive constructions (Bresnan, Cueni, Nikitina, & Baayen, 2007). In contrast, Ivanova, Pickering, McLean, Costa, and Branigan (2012) found that adult L1-English speakers produced double-object sentences with non-alternating verbs no more than 5% of the time when the recipient and theme were both simple nouns (as in (2b)). Thus, in the context of the experiments we report here (using the same materials as Ivanova et al., 2012), the use of non-alternating verbs with the double object is strongly dispreferred to (near-)ungrammatical (perhaps also varying by speaker), though for conciseness we henceforth refer to them as “dispreferred”. We examine here how such restrictions are represented in the minds of highly-proficient L2 speakers, tracing influences of generalization from the L1, and of statistical learning. The fact that the restrictions are not extremely strong makes them an interesting test case to tease apart different ways in which statistical learning can influence their representation.

*L1 generalization.* It is well-established that an L1 exerts some influence on L2 processing, for all types of representation – phonological, lexical, grammatical, and pragmatic (e.g., Bauke, 2020; Birdsong, 2018; Grüter & Hopp, 2021; Hopp & Grüter, 2023; Jarvis, 2012; Kim, Chen, & Liu, 2022; MacWhinney, 2008; Odlin, 2012; Rankin, 2014). Beginner and intermediate L2 learners specifically generalize properties of datives and causatives in L2 from the properties of their L1 (Juffs, 2000; White, 2003). For example, L1-English learners of French assumed that French allows double-object constructions (that is, they judged prepositional objects and double objects as equally acceptable in a preference task; White, 1987; 1991), whereas L1-French learners of English assumed that English does not allow them (that is, they indicated that double objects were not expressed in good English in an intuitive judgement task; Mazurkewich, 1984).

On the basis of such evidence, we can consider a possible role for *L1 generalization* in shaping lexically-specific syntactic restrictions in the L2. In this case, associations between the representations of a verb and a structure in the speakers’ L1 are transferred to the translation of that verb in the L2. Importantly, in this case, such associations persist even for highly proficient speakers who have been immersed in the L2 environment. For example, L1 speakers of a Germanic language such as German would transfer the link between *spenden* [donate] and the double-object structure (e.g., *Der Gast spendet unserem Verein ziemlich viel Geld* [The guest donates our association<sub>DAT</sub> quite a lot of money<sub>ACC</sub>]) to the English verb *donate*. Consequently, L2-English speakers with L1-Germanic languages would represent a link between the English (non-alternating) verb and the double-object structure that does not exist in

the minds of L1-English speakers, and would hence produce dispreferred double-object utterances with non-alternating verbs more frequently than L1-English speakers. This, however, would not be the case for speakers whose L1 does not allow the double-object structure, such as speakers of Romance languages.<sup>3</sup>

*L2 Statistical learning.* Another factor that may shape the representations of lexically-specific syntactic restrictions for proficient L2 speakers is statistical learning – broadly, the formation and refinement of mental representations of linguistic entities on the basis of exposure to them. This includes exposure to abstract structural constituents as well as to specific verb-structure combinations. Of interest here is how much these two sources of information each influence the representations of lexically-specific syntactic restrictions in a proficient L2.

One type of relevant statistical information is about abstract structure. For example, a verb that can be used with a recipient and a theme would accumulate statistical information from exposure to all verbs used with these elements. Such implicit learning of abstract structure is modeled in error-driven learning approaches: Speakers predict language input based on their existing mental representations, and if the input mismatches the prediction, mental representations are adjusted accordingly, to be better able to predict linguistic input in the future (Chang, Dell, & Bock, 2006). The importance of abstract structure in processing in the L1 has been demonstrated through evidence of abstract priming (of well-formed sentences though not dispreferred sentences) from primes with novel, incongruous or altogether missing verbs, i.e., regardless of verb identity (Ivanova et al., 2012; Ivanova, Pickering, Branigan, Mclean, & Costa, 2012; Ivanova, Branigan, McLean, Costa, & Pickering, 2017).

But how much are representations influenced by statistics about abstract structure in the L2? It may be that statistics in the L2 are accumulated for abstract structure without reference to individual verbs – even for representations that obey finer-grained lexically-specific restrictions (such as those of non-alternating verbs). This account predicts overgeneralization: Grouping together statistics on the usage of all verbs with a recipient and theme would result in applying statistics about the usage of alternating verbs to non-alternating verbs. In that case, L2-English speakers would represent double-object utterances with non-alternating verbs differently to L1-English speakers. Consequently, an abstract structural influence for proficient L2 speakers (regardless of their L2) would lead them to use non-alternating verbs with double-object structures at a higher rate than L1 speakers.

But it is also possible that statistics in the L2 are accumulated for individual verbs, and do not generalize across verbs. This can be done by inference from absence, an account proposed to explain how lexically-specific syntactic restrictions are acquired in infancy (Hahn & Oakford, 2008). For example, L1-English-speaking children may acquire the double-object structure by keeping track of the occurrences of a verb in this structure, relative to the occurrences of this verb in other structures (Ambridge et al., 2014). If a verb (e.g., *donate*) never occurs with a given structure (e.g., the double object), every encounter with the verb in a synonymous structure such as the prepositional object (or in any other structure such as a monotransitive) allows the learner to infer that the use of that verb in a double-object structure is ungrammatical (Ambridge, Pine, Rowland, & Young, 2008).

Applied to the representation of lexically-specific syntactic restrictions in the L2, such a mechanism could lead L2 speakers to develop sensitivity to the restrictions comparable to those of L1 speakers

<sup>1</sup> For a discussion on speakers’ preference for the double-object construction when the recipient is a pronoun, please see Goldberg (2011; 2019).

<sup>2</sup> We thank the Editor for these suggestions.

<sup>3</sup> Romance languages are standardly considered to lack the double-object structure, though some researchers have argued that the double-object structure exists in Spanish (Demonte, 1995), French (Fournier, 2010), Portuguese (Torres Morais & Salles, 2010), Romanian (Diaconescu & Rivero, 2007) and Catalan (Pineda, 2013).

(provided they have had sufficient input).<sup>4</sup> If so, L2-English speakers should represent double-object utterances with non-alternating verbs similarly to L1-English speakers. Moreover, they would be sensitive to contexts that make their use more acceptable (such as with a pronoun as recipient) but would show a reluctance to produce such utterances in contexts as the ones used in this study (such as example (2b) above).

#### Testing knowledge of lexically-specific syntactic restrictions with structural priming

To study how the mechanisms reviewed above shape the representation of lexically-specific syntactic restrictions in proficient and immersed L2 speakers, we use structural priming in production, that is, speakers' tendency to produce sentences with previously heard or produced structures (Ferreira & Bock, 2006, p.1; for reviews, see Branigan, 2007; Branigan & Pickering, 2017; Pickering & Ferreira, 2008). For instance, Bock (1986) showed that participants were more likely to produce a double-object sentence such as *A rock star sold an undercover agent some cocaine* after hearing another double-object sentence than after hearing a prepositional-object sentence (see also Mahowald, James, Futrell, & Gibson, 2016, for meta-analytic evidence showing robust effects for structural priming in language production).

Structural priming is sensitive to both verb subcategorization preferences and abstract syntactic structure (Bernolet & Hartsuiker, 2010). It has been observed in interactive language use (Branigan, Pickering, & Cleland, 2000) and across languages (Hartsuiker, Pickering, & Veltkamp, 2004), in children (Huttenlocher, Vasilyeva, & Shimpi, 2004), patients with aphasia (Hartsuiker & Kolk, 1998), and patients with amnesia (Ferreira, Bock, Wilson, & Cohen, 2008).

An important feature of structural priming is that, while it occurs in the absence of lexical repetition, it is enhanced by such repetition. For example, *The monk gives the boy the book* is more strongly primed by a double-object sentence containing *give* than by a double-object sentence containing *show*. This pattern suggests that priming is in part abstract, in part lexical. The enhancement of the magnitude of priming with lexical repetition is known as the *lexical boost* (Pickering & Branigan, 1998) and is most clearly observed with the repetition of head words (verbs: Pickering & Branigan, 1998; nouns: Cleland & Pickering, 2003; see Huang, Liu, Lu, Sun, Wang et al., 2023).

Importantly, cross-linguistic studies have shown priming from one language to the other. For example, Hartsuiker et al. (2004) demonstrated that English-Spanish bilinguals are more likely to use a passive sentence in English after having heard the corresponding structural equivalent in Spanish. Loebell and Bock (2003) showed that fluent German-English speakers were primed to produce a double object or a prepositional object in German after having produced the English equivalents, and vice versa. These findings are consistent with the proposal that L2 learners develop shared (from initially separate) syntactic representations for structures that are the same in the L2 and the L1 (e.g., actives and passives in English and Spanish; Bernolet, Hartsuiker, & Pickering, 2007, 2013; Hartsuiker & Bernolet, 2017). Relevant to the current study, what allows the development of shared syntactic representations is presumably some sort of generalization from the L1. In contrast, representations that differ across languages are not shared (including when a representation is present in one language and missing in another).

There is, however, some evidence inconsistent with an influence of generalization from L1 syntactic preferences to L2 syntactic preferences. Flett, Branigan, and Pickering (2013) asked whether syntactic representations in the L2 are affected by experience only with the L2

<sup>4</sup> This would be a state reached with high L2 proficiency regardless of whether such representations were initially formed partially or completely through influences of L1 generalization and statistical learning of abstract structure.

(*language-specific account*), or with both the L1 and L2 (*language non-specific account*). They compared the magnitude of within-English structural priming from dative sentences (with alternating verbs) of L1-English speakers to that of highly proficient L1-German and L1-Spanish speakers who had English as an L2. Since only German but not Spanish has a double-object structure, an L1 influence (i.e., language non-specific experience) would give rise to between-group differences in baseline double-object production – specifically, more double-object utterances for L1-German speakers (as double objects occur more commonly across German and English combined) than L1-Spanish speakers (as double objects occur less commonly across Spanish and English combined). However, Flett et al. did not find such a difference.

An L1 influence would also give rise to more within-English priming for L1-Spanish speakers than L1-German speakers, because of the tendency for less frequent prime structures to produce larger priming (*inverse preference effect*, Bernolet & Hartsuiker, 2010; Jaeger & Snider, 2013). This is because L1-German speakers would have more experience with double objects (combined from their L1 and L2) than L1-Spanish speakers (who would have encountered double objects in only their L2, but not in their L1). Inconsistent with this prediction, no differences were found between groups in the magnitude of the priming effect. Therefore, these results are more consistent with a lack of L1 influence on L2 structural preferences, supporting a language-specific influence by which preferences in the L2 are affected by only the L2 and are independent of the L1.

Further, a structural priming study has provided insight into the processing of lexically-specific syntactic restrictions in L1. Ivanova et al. (2012) examined the malleability of lexically-specific syntactic restrictions for L1-English speakers (using a design investigating the lexical boost). They found that young-adult L1-English speakers were primed to produce dispreferred double-object sentences with non-alternating verbs only after exposure to prime sentences with the same structure and also the same verb as the targets. There was no priming from well-formed double-object primes with alternating verbs or from dispreferred double-object primes with different non-alternating verbs. The authors interpreted these findings as evidence against generalization (within L1) from both alternating and non-alternating verbs, and in favor of learning or modification of lexically-specific syntactic restrictions on an item-by-item basis (conceptually consistent with a lexically-dependent statistical learning mechanism, see General Discussion). However, it remains an open question whether L2 learning and representation would be shaped in a similar way.

#### The present study

In the present study, we investigate how highly-proficient and immersed L2-English speakers represent lexically-specific syntactic restrictions concerning English non-alternating verbs. We test the contributions of knowledge inherited from the L1 (*L1-generalization*) and of *statistical learning* within the L2, both of abstract structure and of lexically-specific structural information.

To investigate the respective roles of these mechanisms, we conducted two structural priming experiments with highly-proficient and immersed L2-English speakers. The experiments were identical in design and structure to Experiments 3 and 4 from Ivanova et al. (2012), but tested a different population and address different questions, as explained here. Participants produced dative target picture descriptions after reading dative prime sentences. In Experiment 1, primes with non-alternating verbs (dispreferred double objects, e.g., *The waitress returns the swimmer the jug*, as well as grammatical prepositional objects, e.g., *The waitress returns the jug to the swimmer*) were followed by target pictures with different non-alternating verbs (e.g., *demonstrate*). In Experiment 2, double-object and prepositional-object primes with both alternating verbs (e.g., *The nun gives the dancer the jug*) and non-alternating verbs (e.g., *The chef donates the clown the banana*) were followed by targets with non-alternating verbs that were the same as the

non-alternating prime verbs (*donate* in this example). Both experiments thus included conditions to test the influence of abstract statistical learning. A priming effect from different verbs (non-alternating in Experiment 1 and alternating in Experiment 2) is standardly attributed to priming of abstract structure – and finding a different-verb priming effect would provide evidence that the structural representations associated with individual verbs have a common denominator in proficient L2-speakers' minds. Conversely, if proficient L2 speakers draw inferences about each verb's behavior only after encountering uses of that particular verb (that is, represent a specific verb-structure combination only after exposure to that same combination), in Experiment 2 there should be priming only from non-alternating same-verb primes but no priming from alternating-verb primes.

Further, to test the influence of L1 generalization, both experiments tested two groups of L2 speakers: L1 speakers of Germanic languages, which have a double-object structure (henceforth, *L1-Germanic speakers*), and L1 speakers of Romance languages, which do not have it (henceforth, *L1-Romance speakers*). Under L1-generalization, L1-Germanic speakers should generalize lexically-specific syntactic restrictions from L1 translation equivalents, and thus should use the double-object structure with non-alternating verbs in English to a greater extent than L1-English speakers. In contrast, L1-Romance speakers cannot generalize from L1 translation equivalents; they can generalize lexically-specific syntactic knowledge only from other verbs in English (their L2) – whether alternating or non-alternating. An L1-generalization mechanism should therefore yield larger priming for the L1-Germanic group than the L1-Romance group because the double-object structure with non-alternating English verbs would be more acceptable for these speakers (because it is not (near-)ungrammatical in their L1). On the other hand, statistical learning purely within the L2 should not give rise to any difference between groups because representations would be influenced only by usage in the L2 and would not be influenced by characteristics of the L1 (as long as the two groups have similar proficiency and exposure to the L2).

It is of course also possible that influences of the different mechanisms are not independent of one another. As one possibility, patterns of use in the L1 may bias greater reliance on one or another mechanism for representing linguistic entities in the L2. For example, an L1 that allows dative verbs to be used in both prepositional-object and double-object structures (in this study, Germanic languages) may give rise to a representational system in which the structural representations associated with individual dative verbs are more likely to be perceived as related. Such a system may then bias an L2 speaker to confer more weight to abstract statistical learning of dative verbs in an L2 (but, in the case of English, this would lead to overgeneralization, as discussed above).<sup>5</sup>

We also compare the two L2 groups in each experiment with the performance of the L1-English participants in the corresponding experiments from Ivanova et al. (2012). L2 representations that are in some ways different from those of L1 speakers should result in different patterns of priming for L2 speakers versus L1 speakers. An influence of L1 generalization predicts more double-object utterances with non-alternating verbs, and stronger priming of such utterances, for L1-Germanic speakers only, whereas an influence of statistical learning of abstract structure predicts larger effects for both L2 groups (and a combined influence predicts larger effects for L1-Germanic than for L1-Romance speakers, but both larger than those for L1-English speakers). Conversely, L2 representations that are equivalent to those of L1 speakers – presumably developed from lexically-specific statistical learning – should produce equivalent production and priming of double-object utterances with non-alternating verbs for L2 and L1 speakers (given that Ivanova et al., 2012, did not find significant priming in L1 speakers following different non-alternating verbs or alternating verbs).

## Experiment 1

Experiment 1 tested the tendency of L1-Germanic and L1-Romance speakers to produce English double-object structures involving non-alternating verbs after (dispreferred) double-object or (grammatical) prepositional-object sentences with different non-alternating verbs. We were interested in whether they would show a structural priming effect under these conditions.

### Method

#### Participants

A total of sixty participants from the University of Edinburgh community took part in exchange for payment, of which fifty-five were included in the analyses. Twenty-seven participants (18 women, 9 men; mean age = 22.7,  $SD = 2.8$ ) were L1-Germanic speakers: German ( $n = 19$ ), Dutch ( $n = 4$ ), Swedish ( $n = 2$ ), Danish ( $n = 1$ ), and Icelandic ( $n = 1$ ). Four participants in this group were excluded from analyses: three due to a technical error (no audio recorded) and one for reporting extensive use of a Romance language in early childhood. Twenty-eight (23 women, 5 men; mean age = 22.3,  $SD = 3.84$ ) were L1-Romance speakers: Italian ( $n = 8$ ), French ( $n = 7$ ), Romanian ( $n = 6$ ), Spanish ( $n = 6$ ) and Catalan ( $n = 1$ ). One participant in this group was excluded from analyses for being an L1-English speaker who learned Spanish in late childhood. Language proficiency was assessed with a language history questionnaire (summarized in Table 1). Additional analyses with English proficiency as factor in the analyses did not produce any significant results in either this or the following experiment.

#### Materials

The stimuli were the same as in Ivanova et al. (2012); all stimuli are listed in Appendix A of that study). There were thirty-two experimental items consisting of a prime sentence, a verification picture, and a target picture for description. All stimuli and testing materials were in English. The target pictures were 32 black-and-white drawings of transfer events depicting three entities: an object (which could be an apple, a ball, a banana, a book, a cake, a cup, a gun, a hat, or a jug) and two cartoon characters (which could be an artist, a boxer, a burglar, a chef, a clown, a cowboy, a dancer, a doctor, a monk, a nun, a pirate, a policeman, a prisoner, a sailor, a soldier, a swimmer, a teacher, or a waitress). The order of agent and beneficiary was from left to right on half of the pictures, and from right to left on the other half. Below the characters there was a verb in present tense written in capital letters, which participants were instructed to use in their descriptions. This was done to control for the verbs used in participants' descriptions and the relationship between prime and target verbs (and is standard in many priming experiments, following Branigan et al., 2000).

The 32 prime sentences were dative sentences with either a prepositional object or a double-object structure. In the non-alternating verb condition (of interest here), the prime sentences had one of eight non-alternating verbs (*conveys, delivers, demonstrates, describes, displays, donates, returns, and reveals*). The target pictures following these primes also had non-alternating verbs from the same set of non-alternating verbs, but they were paired in such a way that they were different from the prime verbs (e.g., prime: *donate*, target: *reveal*; these pairings were constant across verbs). Fig. 1 shows a sample target picture. There were four target pictures for each of the eight non-alternating verbs. In addition (following Ivanova et al., 2012), there was an Alternating verb “dummy” condition with only double-object primes. It was included to increase participants' exposure to such sentences and thus encourage their production (otherwise highly infrequent with non-alternating verbs). In this condition, the prime sentences and their corresponding target pictures contained one of the following alternating verbs, different between primes (*brings, flings, gives, lends, mails, passes, rents, and tosses*) and targets (*chucks, hands, loans, offers, sells, sends, shows, and throws*). There were four target pictures for each of the eight alternating

<sup>5</sup> We thank an anonymous reviewer for (conceptually) suggesting this point.

**Table 1**  
Participants' language background information.

Group	Average L1 scores			Average English scores				Time residing in current Eng- speaking country in months	
	L1 overall mean proficiency	L1 Age of exposure	L1 age started speaking	Eng overall mean proficiency	Eng age of exposure	Eng age started speaking	Eng % current use		
Exp. 1	L1-Germanic	9.7 (0.6)	0.0 (0.0)	1.4 (0.7)	9.0 (0.8)	6.6 (3.2)	9.3 (2.8)	84.1 (16.3)	16 (13.1)
	L1-Romance	9.8 (0.4)	0.2 (0.6)	1.8 (1.8)	8.8 (0.8)	6.3 (3.4)	8.4 (4.3)	75.5 (24.7)	19 (16.5)
Exp. 2	L1-Germanic	9.8 (0.3)	0.0 (0.2)	1.6 (0.8)	9.1 (0.7)	6.4 (3.7)	9.1 (4.0)	86.4 (13.1)	23 (16.3)
	L1-Romance	10.0 (0.1)	0.0 (0.0)	1.3 (0.6)	8.4 (0.9)	7.0 (2.9)	10.3 (5.4)	68.9 (22.9)	12 (10.2)

*Note.* Overall mean self-rated proficiency scores averaged across five subdomains (spoken comprehension, reading comprehension, fluency, pronunciation, writing). Proficiency self-ratings were given on a scale from 1 (“barely or not at all”) to 10 (“native-like”). Standard Deviations (SDs) are given in parentheses. Eng: English. Missing data points for average calculations: six participants did not report any L1 proficiency ratings; one participant did not report any L1 proficiency ratings and time of residence in current country; one participant did not report any L1 proficiency ratings and L1 age of exposure; one participant did not report any L1 proficiency ratings, L1 age of exposure, and age of starting to speak L1; two participants did not report proficiency ratings for an L1 sub-scale; one participant had seemingly used the proficiency scales in a reversed order and therefore their proficiency scores were not computed in the averages; three participants did not report L1 age of exposure; two participants did not report L1 age of exposure and time of residence in current country; eight participants did not report age of starting to speak L1; one participant did not report L1 age of exposure and age of starting to speak L1; one participant did not report age of starting to speak L1 and ratings for a sub-scale of proficiency in English; one participant did not report age of exposure to English; and one participant did not report time of residence in current country.



Fig. 1. Sample target picture with a non-alternating verb.

verbs. It was a “dummy” condition because there was no corresponding prepositional-object condition, and we calculate priming effects for each verb condition by subtracting the rate of producing one structure after primes with the same structure from the rate of producing this structure after primes with the alternative structure. As priming could not be measured as in the other conditions here and in other related studies, responses in the “dummy” condition were not analyzed.

The distribution of experimental prime sentences was as follows: There were 24 double-object prime sentences (16 with alternating verbs [dummy condition] and eight with non-alternating verbs), and eight prepositional-object prime sentences with non-alternating verbs. The conditions in Experiment 1 are summarized in Table 2, where sample sentence (2) denotes the dispreferred prime structure.

In addition, there were 32 verification pictures that depicted transfer events and characters and objects drawn from the same set as in the target pictures. Half of the verification pictures depicted the event in the preceding prime sentence and thus required a *yes* response, and half differed from the event in the preceding prime sentence and thus required a *no* response. Pictures requiring a *no* response differed from the prime sentence by one entity only (for example, the prime sentence *The teacher describes the apple to the waitress* was followed by a match

**Table 2**  
Sample sentences and characteristics of prime and target sentences in Experiment 1.

Example prime sentence	Primes		Target verb
	Verb type	Structure type	
(1) The artist gives the soldier the banana	Alternating (Dummy)	Double object	Alternating, different
(2) The teacher donates the waitress the hat	Non-alternating	Double object	Non-alternating, different
(3) The dancer donates the cake to the doctor	Non-alternating	Prepositional object	Non-alternating, different

picture depicting a *monk* describing an apple to a waitress).<sup>6</sup>

There were also 96 filler items with the same structure as the experimental items (prime sentence, verification picture, target picture) but using monotransitive prime sentences (e.g., *The artist touches the doctor*, *The teacher eats the banana*). One-third of the fillers contained verbs of Latin origin (e.g., *reprimand*), because non-alternating verbs are typically Latinate (Pinker, 1989). As in the experimental items, half of the filler verification pictures matched the prime sentences preceding them, and half did not.

With the experimental, “dummy” and filler items, four lists were created, such that each list contained 16 experimental items (eight non-alternating double-object primes with different non-alternating targets and eight non-alternating prepositional-object primes with different non-alternating targets), the “dummy” 16 alternating-verb double-object primes with different alternating-verb targets, and the 96 fillers. The order of presentation of items was randomized for each participant and no items were repeated within a list. Between two and four fillers separated experimental items and preceded the first experimental item.

*Language questionnaire:* Participants filled out a questionnaire about demographic and language background information including questions about age of acquisition and proficiency in the participants' languages.

**Procedure**

Participants read written instructions (the same as used by Ivanova

<sup>6</sup> To compare the presence of cognates between English the Germanic versus Romance languages, we used Google Translate to translate all nouns and verbs in the experimental items into all participants' Germanic and Romance L1s. The number of cognates was 50% for Germanic and 40% for Romance languages.

et al., 2012), informing them that they were to alternate between matching and describing pictures, and requesting them to use the verb written under the picture and to describe the pictures within the given time (8 s, see below). They were then familiarized with the cartoon characters and objects they would see in the main experiment. First, they saw each character or object with its name written under it and read the name aloud. Then, they saw the characters and objects without their names, which they were asked to produce. The characters and objects were presented four at a time on a single slide using Microsoft PowerPoint®. Note that this familiarization was not used in Ivanova et al. (2012); it was included here because participants were L2-English speakers and might not always produce the appropriate character and object names. After familiarization, participants completed a set of six practice trials, which were of similar structure to those in the actual experiment.

The experimental trials were presented in a single block. Each experimental trial consisted of a fixation point, which remained in the center of the screen for 700 ms, followed by the prime sentence, displayed for 4000 ms. Then, the matching picture appeared and participants had to press one of two keys on the keyboard to indicate whether the picture matched the preceding sentence (“M” key) or did not match (“N” key). The matching picture disappeared after 3325 ms or immediately after a response was given if it happened before this time. Finally, the target picture remained on the screen for 8000 ms during which participants had to describe the picture using the verb underneath the picture and the next trial began. Presentation times in the current study were slower than the original ones used in Ivanova et al. (2012: 1500 ms for the prime sentence, 2500 ms for the matching picture, and 5000 for the target picture) to ensure that the L2 participants in this study had sufficient time to verify and describe pictures. Presentation times were adapted based on informal pilot data collected from two participants who did not take part in any of the experiments reported here. The matching and target pictures were surrounded by a colored frame as a cue to remind participants which action they had to perform (a green frame for a matching picture; a pink frame for a picture description).

The experiment was presented using the DMDX software (Forster & Forster, 2003), and participants’ answers were recorded by the program. At the end of the experiment, participants were asked to translate into their L1 the eight non-alternating verbs along with eight alternating verbs. Finally, participants filled out language history and debriefing questionnaires. The full experimental session lasted approximately 55 min. All participants gave informed consent at the beginning of the experiment and the study had the approval of the University of Edinburgh’s Psychology Ethics Committee.

### Scoring and data analyses

Scoring was the same as in Ivanova et al. (2012). All participants’ picture descriptions were transcribed and scored as prepositional object, double object, or other sentences based on their syntactic structure. A description was scored as a prepositional object if it had the structure NP V NP *to* NP and began with the agent, followed by the verb, the theme, the preposition *to* and the beneficiary. A description was scored as a double object if it had the structure NP V NP NP, and began with the agent, followed by the verb, the beneficiary, and the theme. Descriptions that did not meet either of these criteria were scored as “other”. These included, for example, trials in which participants did not produce a description, incomplete sentences, answers using different verbs from those on the target pictures, or answers using the prepositional-object structure but with prepositions other than *to* (e.g., *at*). The dummy condition was not analyzed (though we do report the means in Table 3 for comparison).

The rate of double-object descriptions was analyzed with Logistic Mixed-Effects Regression (LMER) models (Baayen, Davidson, & Bates, 2008; Jaeger, 2008). Double-object descriptions were coded as 1, prepositional-object descriptions as 0, and other descriptions as NA. We

report a model analyzing the results of the current experiment, and an additional model comparing the results of the current experiment to an identical one with L1-English speakers (reported in full as Ivanova et al., 2012, Experiment 3). The model specifics are described before the presentation of their results. All models had the maximal random-effects structure justified by the design (Barr, Levy, Scheepers, & Tily, 2013). We used the *glmer* function in the lmerTest package (version 3.1–0, lme4 version 1.1–21) in R (version 3.6.1), and the *bobyqa* optimizer to aid convergence. If the full random-effects model did not converge or gave a singular fit warning, the model was simplified by first removing random-effects correlations, and then removing step-wise the random effects accounting for least variance.

Trial-level data and model specifications for both experiments are publicly available at <https://osf.io/9u6r4/>. The experiments were not preregistered.

### Results

A total of 880 responses were produced in the different non-alternating verb condition. Of these, 775 (88.1%) were scored as prepositional objects, 61 (6.9%) were scored as double objects, and 44 (5%) as others. Table 3 displays the proportions of double-object descriptions per condition for the two L2 groups in both experiments. The mean proportions shown in Table 3 exclude “other” responses (for completeness, proportions by-items and proportions computed including “other” responses are also provided in Appendix A). We also provide those of the equivalent experiments with L1-English speakers from Ivanova et al., 2012, for comparison. Table 4 displays the results of the statistical models.

The statistical model had as fixed predictors Group (Romance, coded as  $-0.5$ , Germanic, coded as  $0.5$ ), Prime structure (prepositional object, coded as  $-0.5$ , double object, coded as  $0.5$ ), and their interaction. The first model without convergence or singular fit errors after simplification is provided in Table 4. The only significant predictor was Prime structure, indicating the presence of a priming effect: Participants produced more dispreferred double-object descriptions after the same type of primes than after well-formed prepositional-object primes. There were no significant differences between the two L2-English groups.

The subsequent model (see Table 4) comparing the L2 groups to the L1-English group from Ivanova et al. (2012) had as fixed predictors Group (first-language-English group, coded as  $-0.5$ , second-language-English groups [i.e., L1-Germanic and L1-Romance groups] were each coded as  $0.25$ ), Prime type (coded as above), and their interaction. The only significant predictor in this analysis was Group, indicating that the L2 groups produced more dispreferred double-object descriptions overall than the L1-English group.<sup>7</sup>

### Discussion

In Experiment 1, L2-English speakers produced more dispreferred double-object descriptions with non-alternating verbs after dispreferred double-object primes with different non-alternating verbs than after well-formed prepositional-object primes with different non-alternating verbs. In other words, there was abstract (different-verb) structural priming for the dispreferred double-object structure, suggesting that uses of this structure across verbs are related in L2 speaker’s minds. This

<sup>7</sup> We also conducted an additional model only on those descriptions by the three groups that followed double-object primes, for comparability with analyses of Experiment 2 involving the L1-English group (see below). This model had Group as the only fixed predictor (L1-English group, coded as  $-0.5$ , L2-English groups, coded as  $0.25$ ). This predictor was significant [*Estimate* =  $3.15$ , *SE* =  $1.17$ , *t* =  $2.68$ , *p* =  $.007$ ], indicating that the L2 groups produced more double-object descriptions after double-object primes than the L1-English group (for whom there was no difference in Ivanova et al., 2012).

**Table 3**

By-participant mean proportion of double objects per condition in Experiments 1 and 2, and in Experiments 3 and 4 from Ivanova et al. (2012).

Group	Prime verb	Target verb	Prime structure		Priming effect
			Double Object	Prepositional Object	
<b>Experiment 1</b>					
L1-Germanic	Alternating (Dummy)	Alternating, different	.25	–	–
	Non-alternating	Non-alternating, different	.10	.06	.04
L1-Romance	Alternating (Dummy)	Alternating, different	.13	–	–
	Non-alternating	Non-alternating, different	.09	.04	.06
L1-English (Exp. 3 Ivanova et al., 2012)	Alternating (Dummy)	Alternating, different	.28	–	–
	Non-alternating	Non-alternating, different	.01	.01	.00
<b>Experiment 2</b>					
L1-Germanic	Alternating	Non-alternating, different	.07	.03	.04
	Non-alternating	Non-alternating, same	.23	.04	.19
L1-Romance	Alternating	Non-alternating, different	.08	.04	.04
	Non-alternating	Non-alternating, same	.23	.04	.19
L1-English (Exp. 4 Ivanova et al., 2012)	Alternating	Non-alternating, different	.01	.00	.01
	Non-alternating	Non-alternating, same	.09	.00	.09

**Table 4**

LMER analyses of the data from Experiment 1.

Model	Predictors	Estimate	SE	z	p
<b>Romance versus Germanic groups<sup>a</sup></b>					
	Group	.26	.71	.36	.71
	Prime structure	.92	.35	2.66	.008
	Group × Prime structure	-.58	.68	-.86	.39
<b>Second-language-English versus first-language-English groups<sup>b</sup></b>					
	Group	2.80	1.02	2.74	.006
	Prime structure	.58	.37	1.55	.12
	Group × Prime structure	1.14	1.32	.87	.39

Note: Specification of the first models without convergence or singular fit errors:

<sup>a</sup>responseType ~ groupRVsG \* primeStructure +

(1 | participant) +

(1 + groupRVsG \* primeStructure || item)

<sup>b</sup>responseType ~ groupNonnatVsNat \* primeStructure

(1 | participant) +

(0 + groupNonnatVsNat \* primeStructure || item)

result is consistent with L2 representations that are not fully lexically-dependent but instead (at least in part) shaped by statistical learning of abstract structure.

Importantly, we did not detect any differences between the two L2-speaker groups – the L1-Germanic group, whose L1 provides a source for generalization of verb-specific behavior, and the L1-Romance group, whose L1 provides no such source. This result is inconsistent with generalizations from the L1 underlying the knowledge of English non-alternating verbs at high levels of proficiency. Such a mechanism would give rise to different patterns between speakers whose L1s have different lexico-syntactic restrictions. Specifically, contrary to our findings, L1-Germanic speakers (who have the double-object structure but with different restrictions for individual verbs) would have used more double objects in English (relative to L1-Romance speakers) and hence produced double-object utterances with non-alternating verbs to a greater extent than L1-Romance speakers (who do not have the double-object structure in their L1).

Lastly, the behavior of L2 speakers in Experiment 1 was different from that of the L1-English speakers in Ivanova et al., 2012, Experiment 3), in that the latter did not show reliable verb-class persistence (i.e., abstract structural priming). This result suggests that, at the moment of testing, lexically-specific syntactic restrictions were not represented in exactly the same way in the minds of L2 and L1 speakers: Both groups of L2 speakers showed similar patterns to each other (regardless of whether the L1 of the L2 speakers allows double-object structures or not), yet distinct from L1 speakers, who showed no evidence for abstract priming.

## Experiment 2

Experiment 1 established that L2 speakers generalize verb behavior across non-alternating verbs. In Experiment 2, we tested the breadth of such abstract generalization – that is, whether a similar effect occurs for alternating verbs. We therefore tested L1-Germanic and L1-Romance speakers' tendency to produce English double-object structures involving non-alternating verbs after (dispreferred) double-object sentences or (grammatical) prepositional sentences involving the same non-alternating verbs or (different) alternating verbs. Experiment 2 thus investigated whether exposure to both verb classes (different alternating verbs and same non-alternating verbs) would produce any differential priming patterns with non-alternating verb targets. Specifically, if knowledge of non-alternating verbs in the L2 is shaped by abstract statistical learning from alternating verbs, we expect priming both from alternating-verb and non-alternating-verb primes to non-alternating same-verb targets, but with stronger priming for the latter because of the lexical-boost effect (Pickering & Branigan, 1998). Conversely, a lexically-dependent statistical learning mechanism predicts priming from non-alternating-verb primes to non-alternating same-verb targets (as for the L1-English speakers of Ivanova et al., 2012), but not from alternating-verb primes.

## Method

### Participants

A total of sixty-four participants from the University of Edinburgh community took part in exchange for payment, of which fifty-six were included in the analyses. Twenty-eight participants (21 women, 7 men; mean age = 24, *SD* = 3.02) were L1-Germanic speakers: German (*n* = 13), Dutch (*n* = 6), Swedish (*n* = 5), Norwegian (*n* = 2), and Danish (*n* = 2). Two participants from this group were excluded, one for not being L1 speaker of a Germanic language, and one for having reported growing up with a non-Germanic language in addition to their L1. Twenty-eight (15 women, 13 men; mean age = 25, *SD* = 4.06) were L1-Romance speakers: Spanish (*n* = 16), Romanian (*n* = 5), French (*n* = 3), Italian (*n* = 2), and Portuguese (*n* = 2). Six participants from this group were excluded for the following reasons: three reported exposure to a non-Romance language from birth, one reported living in an English-speaking country in early childhood, and two had more than eight incomplete answers. Participant characteristics are summarized in Table 1.

### Materials

In this experiment, prime verbs were both alternating and non-alternating (i.e., the Alternating verb condition was not “dummy”).

Alternating and non-alternating prime verbs were the same as in Experiment 1. Verbs in the non-alternating prime verb condition were always the same as the target verbs (which were all non-alternating). As such, four prime conditions, listed in Table 5, were obtained by crossing the factors Prime Verb (alternating, non-alternating), and Prime Structure (prepositional object, double object). Sample sentence (3) in Table 5 denotes the dispreferred double-object structure with a non-alternating verb. With experimental and filler items, four lists were created, such that each list contained 32 experimental items (eight items from each of the four prime conditions in Table 5) and the 96 fillers. The distribution of the experimental items was as follows: There were 16 double-object prime sentences (8 with alternating verbs and 8 with non-alternating verbs), and 16 prepositional-object prime sentences (8 with alternating verbs, 8 with non-alternating verbs). As in Experiment 1, the order of presentation of items was randomized for each participant and no items were repeated within a list.

**Procedure, scoring, and data analyses**

These were the same as in Experiment 1, except that the statistical models had the additional predictor Prime verb type and its interactions. Model specifics are explained below.

**Results**

There were 1792 responses produced. Of these, 1514 (84.5%) were scored as prepositional objects, 160 (8.9%) were scored as double objects, and 118 (6.6%) as others. Of note, among the *other* responses, besides the descriptions listed in Experiment 1, there were instances of ungrammatical double-object structures in which the theme of the sentence immediately followed the verb and the theme was immediately followed by the beneficiary, with a missing preposition (e.g., “*the pirate reveals the jug the soldier*”). This type of response occurred 16 times. In addition, one *other* response was a prepositional-object structure but with the beneficiary and object inverted (“*the burglar conveys the sailor to the cup*”). Proportions of double objects per condition are shown in Table 3.

The statistical model had as fixed predictors Prime verb type (Alternating, coded as 0.5, Non-alternating, coded as -0.5), Group (Romance group, coded as -0.5, Germanic group, coded as 0.5), Prime structure (prepositional object, coded as -0.5, double object, coded as 0.5), and their interactions. The first model without convergence or singular fit errors after simplification is provided in Table 6. This analysis showed that Prime verb type was a significant predictor: Participants produced more double-object descriptions after primes with non-alternating verbs than after primes with alternating verbs. Prime structure was also a significant predictor: There were more double-object descriptions after double-object primes than after prepositional-object primes, that is, a priming effect.

Importantly, there was a significant interaction between Prime verb type and Prime structure: the priming effect was significantly larger for (same-verb) primes with non-alternating verbs than for (different-verb) primes with alternating verbs. To shed light on this pattern, we

**Table 5**  
Sample sentences and characteristics of prime and target sentences in Experiment 2.

Prime sentence	Prime verb type	Prime structure	Target verb
(1) The chef gives the pirate the ball	Alternating	Double object	Non-alternating, different
(2) The chef gives the ball to the pirate	Alternating	Prepositional object	Non-alternating, different
(3) The chef donates the clown the banana	Non-alternating	Double object	Non-alternating, same
(4) The chef donates the banana to the clown	Non-alternating	Prepositional object	Non-alternating, same

**Table 6**  
LMER analyses of the data from Experiment 2.

Model	Predictors	Estimate	SE	z	p
<b>Romance versus Germanic groups<sup>a</sup></b>					
	Prime verb type	-.94	.28	-3.40	<.001
	Group	-.07	.58	-.12	.90
	Prime structure	1.80	.29	6.26	<.001
	Group × Prime structure	-.04	.56	-.07	.95
	Prime verb type × Group	-.09	.60	-.15	.88
	Prime verb type × Prime structure	-1.81	.63	-2.88	.004
	Prime verb type × Group × Prime structure	-.17	1.22	-.14	.89
<b>L2 groups versus L1-English group (after Double-Object Primes only)<sup>b</sup></b>					
	Prime verb type	-2.11	.37	-5.63	<.001
	Group	2.52	.88	2.86	.004
	Prime verb type × Group	1.20	1.26	.95	.34

Note: Specification of the first models without convergence or singular fit errors:

$$\begin{aligned}
 \text{a} \text{responseType} &\sim \text{primeVerbType} * \text{groupRVsG} * \text{primeStructure} + \\
 &\quad (1 + \text{primeVerbType} * \text{primeStructure} \parallel \text{participant}) + \\
 &\quad (0 + \text{primeVerbType} : \text{groupRVsG} + \text{primeVerbType} : \\
 &\quad \quad \text{primeStructure} \parallel \text{item}) \\
 &\quad (0 + \text{primeVerbType} : \text{groupNonnatVsNat} \parallel \text{item}) \\
 \text{b} \text{responseType} &\sim \text{primeVerbType} * \text{groupNonnatVsNat} + \\
 &\quad (1 + \text{primeVerbType} \parallel \text{participant}) + \\
 &\quad (0 + \text{primeVerbType} : \text{groupNonnatVsNat} \parallel \text{item})
 \end{aligned}$$

subsequently ran separate models on the descriptions following primes with non-alternating verbs and primes with alternating verbs, with Group, Prime structure, and their interaction as fixed predictors (coded as above). These models indicated that the priming effect (the Prime structure predictor) was significant following both non-alternating primes [*Estimate* = 2.66, *SE* =.44, *z* = 6.03, *p* <.001] and alternating primes [*Estimate* = 1.00, *SE* =.49, *z* = 2.03, *p* =.04], although the effect was substantially smaller for the latter (resulting in the significant Prime verb type × Prime structure interaction mentioned above). There were no significant differences in the patterns of the two L2 groups (the effect of Group and its interactions were not significant in any of the models).

As in Experiment 1, we also compared the two L2 groups to the L1-English group from Ivanova et al. (2012, Experiment 4). However, the L1-English group had not produced any double-object descriptions after prepositional-object primes, causing the statistical model to overfit and not allow a reliable analysis (e.g., Menard, 2002). For this reason, and following Ivanova et al. (2012), we analyzed only responses following double-object primes (i.e., the primes that produced the priming effect of interest in this study). This model (Table 6) had as fixed predictors Prime verb type (Alternating, coded as 0.5, Non-alternating, coded as -0.5), Group (L1-English group, coded as -0.5, L2 groups, coded as 0.25), and their interaction. This analysis indicated that the L2 groups produced more double-object descriptions following double-object primes than the L1-English group (Group was a significant predictor). Moreover, there were more double-object descriptions following double-object primes in the non-alternating than in the alternating prime-verb condition (Prime verb type was a significant predictor). However, the relation of double-object descriptions across the two Prime verb conditions did not differ between the L1-English and L2 groups (the interaction between Prime verb type and Group was not significant).

**Discussion**

In Experiment 2, L2 speakers of English showed priming from alternating-verb primes to non-alternating-verb targets (i.e., an abstract priming effect), suggesting that the structures used with alternating and non-alternating verbs in English are related in the minds of L2 speakers. This pattern differed from the L1-English speakers in Ivanova et al. (2012), who showed no priming from alternating verbs to non-alternating verbs. Both the presence of priming in L2 speakers in this



condition, and the difference compared to L1-English speakers, are consistent with influences of abstract statistical learning within the L2: They indicate that the structural representations connected to alternating and non-alternating verbs are related in the minds of L2 speakers. They are not consistent with influences of generalization from the L1, which would have predicted different patterns between the L1-Germanic and L1-Romance groups, contrary to our findings.

Importantly, both L1 and L2 speakers produced more double objects after double-object non-alternating same-verb primes than after alternating different-verb primes (i.e., a lexical boost). In addition, the magnitude of the priming effect for the alternating and non-alternating verbs did not differ between L1 and L2 speakers (i.e., no significant by-group interaction); suggesting similar patterns of lexically-driven priming.

## General discussion

In two structural priming experiments in English, we investigated L2-English speakers' representations of lexically-specific syntactic restrictions of verbs, and the combination of factors that shape them: generalization from the L1, statistical learning of abstract structure, and statistical learning of lexically-specific information. Each of the two experiments tested two L2 groups: L1-Germanic speakers (whose L1 allows the double-object structure) and L1-Romance speakers (whose L1 does not allow that structure). In Experiment 1, L2 participants were primed to produce dispreferred double-object structures with non-alternating verbs after (dispreferred) double-object primes with different non-alternating-verbs. In Experiment 2, they were primed to produce dispreferred double-object structures with non-alternating verbs after (grammatical) double-object primes with different alternating verbs. In both experiments, L1-Germanic and L1-Romance speakers did not differ in their patterns of priming. Additionally, in Experiment 2, L2 speakers showed stronger priming after (dispreferred) non-alternating same-verb double-object primes than after (grammatical) alternating different-verb primes; again, L1-Germanic and L1-Romance speakers did not differ in their patterns of priming.

These patterns differ in some important aspects from those found in L1-English speakers in Ivanova et al.'s (2012) experiments. Overall, our L2 participants produced more double objects than Ivanova et al.'s L1-English participants. Additionally, in the current experiments, L2 participants were primed to produce dispreferred double objects (involving non-alternating verbs) after both non-alternating and alternating different-verb double-object primes. In contrast, Ivanova et al.'s L1-English speakers showed no priming at all in these conditions. At the same time, our L2 participants and Ivanova et al.'s participants showed a common pattern, in that priming for non-alternating-verb targets was stronger after (dispreferred) non-alternating same-verb primes than after (grammatical) alternating different-verb primes – a lexical boost effect of a statistically similar magnitude. We discuss these results and their implications in turn.

First, the presence of a priming effect after both different non-alternating verbs and different alternating verbs (of a similar numerical magnitude of around 4%) supports a common representation in L2 speakers' minds of the double-object structure used across both non-alternating and alternating verbs. This result thus points to a role of statistical learning of abstract structure in the representations of non-alternating dative verbs in English for proficient L2 speakers. It also points to a role of abstract statistical learning for the initial formation of such representations in an L2. That is, the existence of a trace of generalization over abstract structure within the L2 implies that lexically-specific syntactic representations in the L2 do not develop from lexically-specific statistical learning from initial stages of exposure, but instead go through a lexically-independent stage along the way (that persists even with high proficiency).

We can exclude the alternative explanation, in which our results reflected only lexically-specific statistical learning (statistics of

individual verbs' usage patterns). In principle, because double-object utterances with non-alternating verbs are not completely ungrammatical but are used sometimes, our L2 speakers' production of double-object utterances with non-alternating verbs could reflect their exposure to exemplars of such use with specific verbs. However, having imperfectly learned the exemplars in a lexically-specific way would predict higher overall production of double-object utterances with non-alternating verbs, but not necessarily that such utterances would be primed by alternating verbs, as we actually found; for such priming to occur, the mental representations of the two need to be related.

Another possible source for the abstract priming we observed could be generalization over semantically related verbs in the L2. If L2 speakers know that verbs with particular meanings (e.g., for dative verbs, *'causing to go and causing to have'*, Pinker, 1989) allow particular structures (e.g., both prepositional objects and double objects), then they may assume that verbs with related meanings allow the same constructions (without having encountered any usage patterns for such verbs). While we cannot exclude such a source of generalization within the L2, we note that the semantic relationships of some dative verbs (both alternating and non-alternating) are not always clear (e.g., *give* and *recommend*). Also, no aspect of our results provides direct evidence for such a mechanism, which should be directly manipulated in future work.

A different possibility is that generalization in the L2 occurred over non-alternating verbs only, which tend to be of Latinate origin. Adult L1-English speakers show sensitivity to the fact that Latinate verbs do not occur in the double-object structure by rejecting double-object uses of novel Latinate-sounding verbs (e.g., *Bart orgulated Marge the package*) but not novel Germanic-sounding verbs (e.g., *Bart naced Marge the package*: Ambridge et al., 2012) – thus, they perceive non-alternating dative verbs as a class. However, if non-alternating verbs were represented as a class distinct from alternating verbs in the minds of L2 speakers, we should have observed stronger priming from different non-alternating verbs than from alternating verbs; instead, the priming effects in the two cases were comparable.

Of note, our L2 participants did not show indiscriminate and overwhelming ungrammatical DO production. For comparison, in the study by Flett et al. (2013), proficient L2 speakers from the same population as the current study showed same-verb priming effects of 33%-44% (L1-Romance and L1-Germanic groups, respectively) for fully-grammatical primes and targets. In contrast, in the current study, both L1-Germanic and L1-Romance showed a 19% priming effect in the ungrammatical same-verb condition (Experiment 2). This result suggests that proficient L2 speakers have some sensitivity to lexically-specific syntactic restrictions that discourage the use of the double object with non-alternating verbs (which they have encountered with minimal frequency in the L2), and that this knowledge is shaped by factors other than the learning of abstract structure in the L2 – namely, statistical learning of verb-specific information. In turn, this observation is consistent with results showing that L2 speakers (including those with lower L2 proficiency than the participants tested here) distinguish between different verb classes and are generally sensitive to when verbs do and do not alternate (e.g., in the causative-inchoative alternation; Montrul, 2001). Contributing to the reason why L2 speakers in our study did not show the same pattern as L1 speakers is the fact that, even if highly proficient, they have still had less experience with the language than L1 speakers.

Relatedly, the presence of a lexical boost effect for both L2 and L1 speakers shows that both L2 and L1 speakers are more likely to use uncommon – even strongly dispreferred – verb-structure combinations after experiencing the same combinations immediately beforehand. This pattern suggests that lexically-driven priming does play a role in the representations of lexically-specific syntactic restrictions (and the priming of ungrammatical verb structure combinations) in the L2, as Ivanova et al. (2012) showed for L1. Lexically-driven priming naturally prevents overgeneralizing, in that a speaker would only produce a verb-

structure combination they have encountered. As such, it seems a helpful mechanism for learning in an L2.

We note that lexically-driven priming is known to be short-lived (e.g., Hartsuiker et al., 2008), and thus it is not immediately clear how it might produce effects of long-term learning that we speculate here have shaped (though not exclusively) the formation of lexically-specific syntactic restrictions in the L2. However, as argued in Ivanova et al. (2012), repeated associations between particular verbs and particular structures should still be strengthened over time – otherwise, it would be unclear how speakers end up acquiring verb biases and lexically-specific syntactic restrictions. Such learning could happen via an implicit learning mechanism (Coyle & Kaschak, 2008; what we call here lexically-dependent statistical learning) or via the accumulation of explicit memory traces (Chang et al., 2006), and would be akin to the item-based learning mechanism proposed for L1 acquisition (Tomasello, 2000). In fact, even if the lexical boost itself is short-lived, it could be the resulting production act that strengthens production procedures and produces learning.

A further important finding was that we did not detect differences in priming between the L1-Germanic and L1-Romance groups in either experiment. This pattern is inconsistent with an L1-generalization mechanism, which would give rise to different patterns between speakers who can inherit the patterns of use of double-object verbs from their L1 (here, the L1-Germanic group), and speakers who cannot (here, the L1-Romance group). We therefore find no support for the hypothesis that the lexically-specific structural preferences of highly proficient L2 speakers who are immersed in the L2 environment are shaped by their L1 (and thus could not assess the hypothesis that this mechanism would influence the amount of abstract statistical learning). This conclusion is consistent with the results of Flett et al. (2013), who also did not find any influence of L1 on the abstract structural preferences (for grammatical utterances with alternating verbs) of highly proficient L2 speakers from a similar population as the participants of this study. There is an apparent inconsistency between these findings and evidence of L1 influences at earlier stages of L2 acquisition (e.g., Montrul, 1997; Juffs, 2000). It is likely that these differences reflect differences in proficiency.

Our results have implications for some of the factors that could contribute to successful L2 acquisition. We found that L2 knowledge of lexically-specific syntactic restrictions was shaped by both abstract and lexically-dependent statistical learning. One implication of these findings is that abstract statistical learning alone is not sufficient for the learning of fine-grained restrictions. Our results thus suggest that varied exposure is especially important for developing advanced knowledge of an L2, to the extent that item-based learning seems to be an important mechanism to develop full knowledge of the restrictions.

Our results also have implications for language change. Language change happens in a speech community when its members adopt certain innovations and reuse them in their own speech (thus, contribute to their diffusion: Milroy, 1992). A number of researchers have proposed that L2 speakers may play a particularly important role in diachronic language change (specifically, contact-induced language change; Matras & Sakel, 2007), and have suggested that research on bilingual language processing could give insights into how such change is initiated and diffused (e.g., Hundt, Mollin, & Pfenninger, 2017; Meisel, 2011; Westergaard, 2019). Syntactic priming has been identified as a relevant mechanism in this respect (e.g., Fernández, De Souza, & Carando, 2016; Jäger & Rosenbach, 2008; Kootstra & Muysken, 2019; Pickering & Garrod, 2017).

Our results provide evidence consistent with these proposals and suggest that L2 speakers may be especially likely to be diffusers. This is

because our L2 participants were more susceptible to influences regarding their grammatical knowledge, even when it resulted in producing utterances that would be strongly dispreferred for most L1-speakers. This susceptibility may make it more likely that L2 speakers produce ungrammatical or dispreferred utterances more frequently and after less exposure than L1-speakers. Such utterances may then spread among L2 speakers, creating a community of speakers that produce them, which in turn may make it more likely that L1 speakers adopt them. This observation seems particularly relevant for English because it is spoken by a large number of L2 speakers around the world.

In conclusion, our study suggests that lexically-specific syntactic restrictions in the L2 are shaped by both abstract and lexically-dependent statistical learning, but not by generalization from the L1. Specifically, we showed that highly-proficient and immersed L2 speakers of English have some sensitivity to the lexically-specific syntactic restrictions that make the use of certain dative verbs with the double-object structure dispreferred in their L2, and we attributed it to the influence of frequency of exposure to such structures in the environment. However, we also showed that proficient L2 speakers have a representational association between the syntactic behavior of both non-alternating and alternating verbs (presumably reflecting statistical learning of abstract structure), which we had not detected for L1 speakers in prior work. Lastly, for these highly proficient L2 speakers, we did not detect a role of the L1 contributing to their representation of lexically-specific syntactic restrictions.

#### CRedit authorship contribution statement

**Mariana Vega-Mendoza:** Conceptualization, Methodology, Formal analysis, Software, Investigation, Data curation, Writing – original draft, Project administration, Funding acquisition. **Iva Ivanova:** Conceptualization, Methodology, Software, Formal analysis, Writing – original draft, Funding acquisition. **Janet F. McLean:** Methodology, Writing – review & editing. **Martin J. Pickering:** Conceptualization, Resources, Writing – review & editing, Funding acquisition. **Holly P. Branigan:** Conceptualization, Resources, Writing – review & editing, Funding acquisition.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### Data availability

Trial-level data and analysis code are publicly available on the Open Science Framework (<https://osf.io/9u6r4/>).

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#### Appendix A

Additional tables of mean proportions of double-object descriptions. Mean proportion of double-object responses computed excluding “other”

responses by-items are presented in Table A1. Tables A2 and A3 show mean proportion of double objects computed across all response types, by subjects and by items, respectively.

**Table A1**  
By-item mean proportion of double-object responses per condition (excluding “other” responses).

Group	Prime verb	Target verb	Prime structure		Priming effect
			Double Object	Prepositional Object	
<b>Experiment 1</b>					
L1-Germanic	Alternating (Dummy)	Alternating, different	.25	–	–
	Non-alternating	Non-alternating, different	.10	.06	.03
L1-Romance	Alternating (Dummy)	Alternating, different	.13	–	–
	Non-alternating	Non-alternating, different	.10	.04	.06
<b>Experiment 2</b>					
L1-Germanic	Alternating	Non-alternating, different	.07	.03	.03
	Non-alternating	Non-alternating, same	.24	.04	.20
L1-Romance	Alternating	Non-alternating, different	.09	.04	.05
	Non-alternating	Non-alternating, same	.24	.04	.20

**Table A2**  
By-participant mean proportion of double-object responses per condition (including “other” responses).

Group	Prime verb	Target verb	Prime structure		Priming effect
			Double Object	Prepositional Object	
<b>Experiment 1</b>					
L1-Germanic	Alternating (Dummy)	Alternating, different	.23	–	–
	Non-alternating	Non-alternating, different	.09	.06	.03
L1-Romance	Alternating (Dummy)	Alternating, different	.13	–	–
	Non-alternating	Non-alternating, different	.09	.04	.05
<b>Experiment 2</b>					
L1-Germanic	Alternating	Non-alternating, different	.06	.03	.03
	Non-alternating	Non-alternating, same	.22	.04	.18
L1-Romance	Alternating	Non-alternating, different	.08	.04	.04
	Non-alternating	Non-alternating, same	.22	.04	.18

**Table A3**  
By-item mean proportion of double-object responses per condition (including “other” responses).

Group	Prime verb	Target verb	Prime structure		Priming effect
			Double Object	Prepositional Object	
<b>Experiment 1</b>					
L1-Germanic	Alternating (Dummy)	Alternating, different	.23	–	–
	Non-alternating	Non-alternating, different	.09	.06	.03
L1-Romance	Alternating (Dummy)	Alternating, different	.13	–	–
	Non-alternating	Non-alternating, different	.09	.04	.05
<b>Experiment 2</b>					
L1-Germanic	Alternating	Non-alternating, different	.06	.03	.03
	Non-alternating	Non-alternating, same	.22	.04	.18
L1-Romance	Alternating	Non-alternating, different	.08	.04	.04
	Non-alternating	Non-alternating, same	.22	.04	.18

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