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Morphosyntactic underspecification affects the processing of verbal forms at different levels of abstraction in L1 and L2 German

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Abstract

Using a priming paradigm, we investigated the processing of overtly identical verb forms with different sets of morphosyntactic features in L1 and L2 German. We found that more specific functions of a verb (inflected verbs) were better primes for less specific verb functions (past participles) than vice versa. For L1 speakers, these priming asymmetries were observed regardless of whether the lexical verb was repeated in prime and target or not (i.e., priming also for abstract configurations). For L2 learners, a similar but not native-like asymmetric priming pattern was seen only with repetition of the lexical verb. It was absent when the verb was not repeated. We conclude that in L2, morphosyntactic information is processed more on a lexical, item-based level compared to L1. We discuss our results in the context of several accounts, e.g., Shallow Structure Hypothesis, Declarative Procedural Model and the Ontogenesis Model of the L2 Lexical Representation.

1. Introduction

Differences in the processing of grammar in native and non-native languages have long been the focus of psycholinguistic research. In this study, we address the question whether lexical access to verbs differs depending on the degree of their grammatical specification (i.e., the amount of morphosyntactic features they express) and whether the grammatical representation is structured differently in L1 and L2. We further explore whether L1 and L2 grammar processing differs at the abstraction level on which the processing systems operate, with the hypothesis that L2 processing might be more idiosyncratic, i.e., more tied to individual lexical items with fewer indications of more abstract, generalised representations than in L1.

To produce grammatically correct sentences or comprehend written or spoken language, language users must be able to process morphosyntactic information that mediates the grammatical relationships between word forms in a phrase or sentence. Words differ in the amount of morphosyntactic features they comprise: verbs typically express more grammatical features than nouns, but there is great variation across languages. Prominent L1 psycholinguistic models assume that morphosyntactic features and their values have generic representations and are accessed during grammatical encoding either through the lemma (Dell, 1986; Levelt et al., 1999) or independently from it (Caramazza, 1997).

Inflected word forms related to the same stem may differ in the amount of grammatical information they subsume. For example, while inflected verbs in German carry information about person and number (e.g., *du spiel-st* [2nd person, singular] – "you play") infinitives do not (e.g., *zu spiel-en* – "to play"). The verbal form with the affix *-st* is thus morphosyntactically more specific than the infinitive with the affix *-en* because it comprises more morphosyntactic features.

Research on morphosyntactic (under)specification provides evidence that differences in morphosyntactic specificity are reflected in priming asymmetries. In their unimodal priming experiments, Schriefers et al. (1992) found asymmetries in repetition priming between four types of German inflected adjective forms. However, they explained these asymmetries through different frequencies of the suffixes. Clahsen et al. (2001) addressed this topic more systematically in their cross-modal priming study. Through additional manipulations, the authors explained priming asymmetries by differently complex morphosyntactic feature specifications, excluding frequency effects as the cause. More specific forms (e.g., *klein-es* – "little" [-obl, -masc, - fem, -pl]) facilitated recognition of less specific forms (e.g., *klein-e* – "little" [-obl]) more than vice versa. Such differences between inflected adjective forms with different degrees of morphosyntactic specification are also supported by corresponding processing

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differences observed in ERP studies on inflected adjectives in L1 German (e.g., Leminen & Clahsen, 2014; Opitz et al., 2013).

While adjective inflection in German has attracted substantial attention in psycholinguistic research on morphosyntactic feature specification, verbs, which are the focus of the present study, have been explored to a lesser extent. The only such research focussed on irregular verbs that comprise lexically conditioned stem alternations (e.g., Regel et al., 2015). In several cross-modal priming studies (Bosch et al., 2019; Clahsen et al., 2002; Krause et al., 2015), the priming direction of different stem forms of irregular verbs (e.g., *warf-* → *werf-* vs. *werf-* → *warf-*; "threw" → "throw" vs. "throw" → "threw") was manipulated and the facilitation compared to full repetition priming (e.g., *warf-* → *warf-*). The results again showed that more specific forms (e.g., *warf-* "threw" which is specified for [+ past] in contrast to *werf-* "throw") led to more efficient (near-repetition) priming if the target verb stems were less specific (*werf-* "throw") than vice versa. It remains open whether similar effects of morphosyntactic feature specification can be found also in lexically unconditioned regular conjugation. This is the first aspect that we address in the present study.

Occasionally, modulation of priming effects by morphosyntactic feature specification in verbs was also observed in studies that primarily focus on other research questions. For instance, Bordag and Opitz (2021) investigated the representation of formally identical word forms presented in disambiguating minimal syntactic contexts. They observed that German infinitives (e.g., *mieten* – "to rent") partially primed form-identical inflected verb forms (e.g., *wir mieten* – "we rent"). Exploring the reversed priming relation, Opitz et al. (2022) found that inflected verb forms fully primed infinitives both in L1 and L2 German. Infinitives express fewer grammatical features than finite forms as they lack subject agreement, i.e., they do not express number and person (Chamoreau & Estrada-Fernández, 2016). Overall, these results indicate that inflected, more specific verb forms function as better primes for less specific targets comprising fewer features than vice versa.

As demonstrated in numerous studies, grammar acquisition and efficient use seem to pose a bigger CHALLENGE TO L2 LEARNERS than to native speakers, yet the results are not conclusive. Though evidence has been reported indicating that L2 learners process inflection in a native-like manner (i.e., via the constituents of morphologically complex words) and are thus sensitive to the morphological structure of inflected forms (e.g., Coughlin et al., 2019; Coughlin & Tremblay, 2015; Feldman et al., 2010; Foote, 2017), many priming studies fail to find evidence for morphological decomposition in inflection in L2 (e.g., Clahsen et al., 2010; Jacob et al., 2013, 2018; Neubauer & Clahsen, 2009; Silva & Clahsen, 2008). Reduced sensitivity to morphosyntax in L2 has also been demonstrated in research on priming effects between different sets of morphosyntactic features, though these results are not completely conclusive. While studies employing unmasked priming (Bosch & Clahsen, 2016; Bosch et al., 2017) report native-like performance in L1 and L2 German, masked priming experiments (Bosch & Clahsen, 2016) and ERP results (Bosch et al., 2017) suggest differences between L1 and L2 regarding the grammatical processing of differently specific adjective forms.

Potential differences in processing of morphosyntactic features in L1 vs. L2 have been addressed also for verbs; however again only regarding stem alternations of irregular verbs in German. Krause et al. (2015) reported results of a cross-modal priming experiment which replicated the previous findings of asymmetric priming in L1. However, for non-native participants, the asymmetry was reversed, and more specified stem variants led to reduced priming of less specific targets. The authors suggested that stem allomorphy is represented differently in L1 and L2. They argued that priming asymmetries obtained for native speakers can be explained in terms of structured lexical entries with morphosyntactic features (see also Clahsen et al., 2001), while late-learned L2 relies less on morphosyntactic information, and (surface) form and meaning are associatively organised in the L2 lexicon.

Several THEORETICAL ACCOUNTS can explain/assess the observed L1 vs. L2 differences in priming patterns between word forms with different morphosyntactic specifications. The Shallow Structure Hypothesis (SSH; Clahsen & Felser, 2006, 2018) suggests that L2 learners struggle with real-time processing of hierarchical structures and that they make less use of abstract syntactic elements (e.g., movement traces). Instead, they rely more on alternative information like semantics, pragmatics, surface information, or associative patterns. Bosch and Clahsen (2016) propose that reduced priming in L2 may result from difficulty accessing detailed morphosyntactic information in primes. Neubauer and Clahsen (2009) attribute shallow processing to L2 learners relying more on lexicon-based processing (whole word form representations) rather than morphological decoding. Thus, they relate the issue to problems with pre-lexical decomposition of inflected word forms in L2 (see also Kirkici & Clahsen, 2013).

The Declarative/Procedural Model (DP model; Ullman, 2004, 2005, 2020) relates native-nonnative differences in grammar processing to maturational aspects and to the involvement of different memory systems. Two memory systems are distinguished for L1 processing: the declarative system stores memorised words and sentences while the procedural system subserves the processing of combinatorial rules. Due to maturational processes in childhood, the weighting of both memory systems in language processing changes. While declarative memory becomes more important, the procedural system is attenuated. Due to this maturational shift, L2 processing relies dominantly on the lexical memory system and to a much lesser extent on the procedural system. Consequently, reliance on morphological computation, which relies on the procedural memory system, is reduced in L2.

However, the two approaches do not contradict each other, and have recently been brought even closer: Bosch et al. (2019) and Veríssimo et al. (2018) investigated the role of maturational processes and age of acquisition (AoA) in asymmetric priming patterns between verb stem alternations. Bosch et al. (2019) found that the asymmetry in priming between more specific-to-less specific versus less specific-to-more specific verb stems was systematically affected by AoA. The priming advantage of more specified-to-less specified stems (*wirf-* → *werf-*) gradually declined with increasing AoA from 0 up to 11 but flattening from 11 and later. The authors interpreted their findings as evidence for a critical period for the morphological organisation of the lexicon.

The authors further proposed that non-native priming effects between less and more specified forms might arise due to weaker links between more specified forms and their morphosyntactic features, or, alternatively due to weaker links between differently specified stems within a structured lexical entry (e.g., irregular verb stems). This approach departs from the interpretation of failed inflection decomposition as the dominant cause of L2 morphosyntactic processing problems. Rather, it is consistent with the

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assumptions of the Ontogenesis Model of the L2 Lexical Representation (OM; Bordag et al., 2021, 2022) and the related Fuzzy Lexical Representation (FLR) Hypothesis (Cook & Gor, 2015; Gor & Cook, 2020; Gor et al., 2021). The OM assumes that lexical representations develop on several dimensions: linguistic domains (phonological, orthographic, semantic, morphosyntactic), mappings between the domains, and networks of lexical representations. During the process, the degree of fuzziness decreases until a target stage (so-called 'optimum') is (ideally) reached. Fuzzy representations are described as having imprecise or low-resolution encoding of at least one of the linguistic dimensions/domains. At the mapping dimension, fuzziness is operationalised as weak links between the domains. Within the OM, problems in the retrieval of morphosyntactic information might be thus accounted for by deficiencies in their encoding at the morphosyntactic domain or in deficiencies in their mapping to other domains. In the terminology of the OM, it is the dimension of mapping between the phonological and grammatical/morphosyntactic domain, to which the "weaker links" in Bosch et al. (2019) refer to.

Interestingly, psycholinguistic accounts like the SSH and the DP model suggest that differences in L1 and L2 processing of grammatical information are related to differences in the interaction between grammar and lexicon. L2 learners may lean towards whole word form retrieval (SSH) or have reduced procedural memory involvement, shifting towards the declarative system (DP model). Both assumptions indicate stronger reliance on the lexicon for grammatical processing in L2 compared to L1.

The general implication of such a relationship is that grammatical processing in L2 proceeds on a less abstract level and is more idiosyncratic or item-based, i.e., more bound to individual items in the mental lexicon – a hypothesis tested also in our study.

The implication of less abstract L2 grammar representation/processing is also supported by studies employing a different approach. Pinker (2009) proposed that during the acquisition of inflection word specific paradigms are constructed first (i.e., inflected forms of a word are collected for the grammatical contexts in which they appear). Only then the learner gradually constructs structured sets of these forms, from which shared units can be extracted (such as the stem and inflectional endings). This process results in generalised paradigms consisting of a set of rules or rule-like operations to map grammatical functions to affixes (e.g., in English *X* → *X-ed*, +past) (see also Veríssimo et al., 2018). Blom et al. (2006) propose that generalised paradigms constructed by (late) L2 learners are smaller and not appropriately constrained.

This view is not dissimilar to Construction Morphology (CxM; Booij, 2010) and Relational Morphology (RM; Jackendoff & Audring, 2020) approaches, with the difference that construction-based theories distance themselves from the grammar-lexicon dichotomy and describe generalised schemas not as procedural rules, but as abstract entries in the extended lexicon. These schemas can be at various levels of generalisation, depending on the level of achieved abstraction similarly to Pinker's and Veríssimo's description. Giraudo and Dal Maso (2016) explicitly note that by transferring morphological analysis to the area of lexicon, such theories also challenge the "non-operative decomposition" perspective as a procedural cause for the difference between L1 and L2 processing (see, e.g., Kirkici & Clahsen, 2013, pp. 786-87).

In our study, we directly test the hypothesis that L2 acquisition may be more limited to the first, item-based stages, i.e., to the construction of word or lexeme specific configurations, and that L2 learners' ability to proceed to the construction of generalised, more abstract configurations may be compromised.

2. The present study

Most previous research examining the modulation of priming effects by morphosyntactic feature specification was performed in L1 German and focussed on nominal, in particular adjective declension, or on irregular verbs (stem alternations). In almost all cases only isolated word forms were tested. We consider this point critical, since German, like all fusional languages, exhibits extensive syncretism and word forms are often ambiguous when presented in isolation. The accurate function of a word form (or its suffix) is thus determined only by its context, indicating which morphosyntactic features with which values need to be retrieved. As demonstrated particularly in research on grammatical gender processing (Bordag et al., 2006; Levelt et al., 1999; Roelofs et al., 1998; Schriefers, 1993), retrieval of morphosyntactic features can be bypassed when these features are unnecessary for processing. It is unclear how this aspect affects, e.g., the processing of isolated inflected adjective forms (e.g., *rotes* – "red" [nominative/accusative, neuter, singular]) which never appear without syntactic context in natural language. This seems to be even more problematic when forms that are primed are ambiguous in their grammatical function. Target forms like *ändern* ("change") are often supposed to be parsed as infinitives (see, e.g., Jacob et al., 2018), but they are identical with inflected forms of 1st or 3rd person plural *wir/sie ändern* ("we/they change"). In the current study, we tried to raise the ecological validity of our research in this respect by employing a modified priming paradigm and presented all inflected forms in non-ambiguous syntactic contexts.

Moreover, as pointed out also by Bosch et al. (2019), the studies on underspecification of stems of irregular verbs address lexically conditioned inflection that concerns a very special subset of irregular German verbs with stem changes (*sterb - stirb - starb*, "to die"). In contrast, we decided to examine forms representing completely regular, productive affix formation that does not contain lexically conditioned, unproductive stem alternations. Differences in processing of these two types of inflection could thus be expected as they might be subject to different storage and processing. In the present study, we use regularly inflected verb forms and regular non-finite forms (past participle) to explore whether word forms with a different degree of specificity are processed differently. In contrast to infinitives that appear in the studies of Bordag and Opitz (2021) and Opitz et al. (2022) that are used as citation forms in dictionaries and are thus typically the first verbal forms that L2 learners get acquainted with, past participles are acquired later and their structure is more complex compared to infinitives.[1] Irregular participles in German are formed with the suffix *-(e)n* and sometimes also include alterations of the stem (e.g., *singen - gesungen;* "sing" – "sung"). In contrast, regular participles, which we test in the present study, are always formed through suffixation of *-t* and do not involve any alterations on the stem (e.g., *reden - geredet* – "talk" – "talked"; *verarbeiten - verarbeitet* – "to process" – "processed"). If a verb has no prefix or a separable prefix, the additional past participle prefix *ge-* is typically inserted right in front of the stem (*ge-redet* – "talked"; *aus-ge-arbeitet* – "elaborated"). If the verb has an inseparable prefix, the prefix *ge-* is omitted (*verarbeitet* – "processed").

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In the present study, we took advantage of the fact that participle forms of regular verbs with inseparable prefixes are form-identical with the inflected form of the 3rd person singular present tense (*verarbeitet* – "processed [participle]"; *er verarbeitet* – "he processes"). Importantly, comparing homonymous inflected verb forms and participles excludes potential form-related confounding. Neither differences in form frequency nor differences in form-overlap would influence the processing of inflected and participle forms of such verbs. Since the forms are presented in minimal syntactic contexts, their function is disambiguated.

Though formally identical, the investigated German verb forms differ in their morphosyntactic specification. The relevant set of features for German verbs comprises: [V, TENSE, PERSON, NUMBER, MOOD, VOICE] (Audring, 2019, p. 292). While the 3rd person singular is specified for all these features, the past participle lacks the person and number specification, and is therefore a morphosyntactically less specified form. Based on previous research on morphosyntactic specificity, we thus expect that the 3rd person singular form (*er verarbeitet* "he processes") is a better prime for the less specified participle form (*er hat verarbeitet* "he (has) processed") than vice versa.

In Czech, the native language of our L2 participants, the situation is very different. The set of verbal features includes additional features for aspect and conjugational class, and with some forms gender. In addition, the past participle is specified for more features than the 3rd person singular (see supplementary table S1 with the corresponding verbal paradigms):

- Czech 3rd person singular: [V, PERSON, NUMBER, TENSE, MOOD, VOICE, ASPECT, CONJ. CLASS]
- Czech past participle: [V, (PERSON)[2], NUMBER, TENSE, MOOD, VOICE, ASPECT, GENDER, CONJ. CLASS]

With respect to the form properties, the German syncretism between the past participle and the 3rd person singular of the targeted verb type (regular verbs with separable prefix) does not exist in Czech – the present tense forms and the participles have completely different inflectional affixes (see table S1).

Given these differences between German and Czech verbal morphology, Czech L2 learners cannot simply transfer the configurations from their L1 into their L2 but need to establish L2 specific feature configurations for the L2 verbal forms.

To sum up, in the present study, we address four main objectives.

First, we look for evidence for priming between morphosyntactic features in the verbal domain, using lexically unconditioned regular verb forms. We expected that the 3rd person singular forms would be better primes for the participle forms than vice versa.

Second, we used homonymous verb forms (*er - besucht* – "he visits" vs. *er hat - besucht* "he (has) visited") to exclude form-related confounds. If the effects were bound to the form properties themselves (frequency, overlap), we should observe no differences, since the forms are identical. If, however, the processing of the morphosyntactic features depends primarily on the function of the form, we expect to observe asymmetrical priming patterns.

Third, we explore whether the priming effects were item-based – i.e., bound to a particular lexical item – or whether they also reflected processing on a more abstract level. If there are generalised, lexeme independent sets of morphosyntactic features that represent, e.g., the 3rd person singular or past participle (e.g., in English $X \rightarrow X\text{-}ed$ [past], $X \rightarrow X\text{-}s$ [3rd person, singular, present]), it should be possible to prime such abstract representations across lexemes. We thus tested both morphosyntactic configurations (3rd person singular, past participle) and included 'lexical repetition' as a factor which encoded whether either the same verb or a different verb appeared in prime and target in these contexts.

These three objectives were tested for native processing in Experiment 1. The experiment also served as a test to validate the modified priming paradigm, in which form-identical critical words were presented in minimal syntactic contexts, and which has been employed only occasionally before (see Bordag & Opitz, 2021; Opitz et al., 2022). For the fourth objective, we tested non-native participants in Experiment 2 in order to compare morphosyntactic feature processing in L1 and L2. Previous research indicates that morphosyntactic processing might be compromised even in L2 advanced learners. We thus asked whether differences in priming potentials of differently specific morphosyntactic feature sets can be observed in L2 at all (i.e., as reflected in asymmetric priming). Additionally, we wanted to test whether the processing of advanced L2 learners operates on a similar abstraction level as in L1 or whether it is more item-based as implied by several theoretical approaches (e.g., SSH, DP, see above). As in Experiment 1, we therefore compared the priming between morphosyntactic functions (or configurations, i.e., participle vs. inflected verb) in either the presence or absence of the same lexical verb in prime and target.

2.1 Experiment 1

In this experiment, we addressed the first three above-mentioned objectives for native processing. We employed a modified priming paradigm (for a similar approach see Bordag & Opitz, 2021). Instead of presenting isolated words, we measured reaction times to morphosyntactically ambiguous target word forms that were embedded in minimal phrasal context that determined their grammatical function (e.g., *er hat BESUCHT* – "he (has) visited", see examples below).[3] The grammatical context and the critical word were presented in a sequential manner: first the linguistic material that preceded the critical word (i.e., the context, e.g., *er hat* "he has"), and then the critical word (e.g., *BESUCHT* "visited") was presented. That way, reaction times to the ambiguous critical target word could be measured. Participants had to decide whether the critical word was a correct (grammatical) continuation of the phrase and latencies of their responses were measured. Target phrases were preceded by other phrases that functioned as primes. Primes either a) contained the same lexical verb form (*BESUCHT* – "visited"), or not, and b) either had the identical syntactic context (e.g., *sie hat* – "she has"), or not (for details and examples see Methods below).

A full repetition of prime and target (e.g., *er BESUCHT* → *er BESUCHT*, or *er hat BESUCHT* → *er hat BESUCHT*) served as a baseline for which we assumed that it leads to full priming. The priming potentials of all other conditions were then compared to that full-repetition baseline to evaluate whether they elicit priming to the same extent as the baseline – or whether priming was reduced.

For conditions in which the same lexical verb was repeated in prime and target but in distinct functions, we hypothesised that asymmetrical priming should be observed. Based on previous findings in the literature (see above) we assumed that in the inflected verb → participle condition (*er BESUCHT* → *er hat BESUCHT*), the less specific (participle) target forms should be

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facilitated by the more specific (inflected verb) prime forms to the same extent as in the corresponding full-repetition priming condition (participle → participle). In contrast, in the participle → inflected verb conditions (*er hat BESUCHT* → *er BESUCHT*), not all morphosyntactic features of the target can be preactivated by the less specific prime. Therefore, we expected reduced priming relative to the corresponding full-repetition condition (inflected verb → inflected verb).

For conditions in which a different lexical verb was presented in prime and target and in which only the morphosyntactic context was either the same or different, we expected slower reaction times in general. If morphosyntactic configurations are represented and primed on a generalised, abstract level, we should observe asymmetric priming here along the same logics and pattern as in the conditions with the same lexical verb. If the morphosyntactic configurations are idiosyncratic and bound to individual lexical items, no priming between configurations of two different verbs would be expected.

Method

Participants.

Forty-eight German native speakers, mostly university students, participated, 32 of them female, mean age 28.1 years (range 20-43, SD = 5.6). They received monetary compensation.

Materials

Thirty-two German verbs were selected that form their past participle without additional prefixing but with regular affixation of word final *-t* (e.g., *besuch-t* – "visited")[4]. These forms are thus form-identical with the inflected form for 3rd person singular present tense. The stimuli were carefully selected so that the verbs were of average or high frequency (ranged between frequency class 9 and 16 according to Leipzig Wortschatz Projekt[5]) and well known to L2 learners at B2 level, as confirmed by a pretest.[6]

All verbs in the target phrases were embedded in short phrases that unambiguously marked their syntactic function: they were either combined with a personal pronoun and therefore unambiguously presented as verbs inflected for 3rd person singular in present tense, e.g., *er beobachtet* ("he observes"), or they were preceded by a personal pronoun and an auxiliary verb (*er hat* – "he has") so that they unambiguously represented past participles, e.g., *er hat beobachtet* ("he (has) observed"). Thus, for each item there were two target phrases, one in which the verb appeared as an inflected verb and one in which it appeared as a participle.

Target phrases were combined with different related prime phrases that constitute the eight conditions of the experiment. The conditions were formed by completely crossing the three factors Target Form (inflected verb vs. participle) x Function Alternation (i.e., whether the same or a different morphosyntactic context appeared in prime and target) x Lexical Repetition (i.e., whether the same or another lexical verb appeared in prime and target). While the factors Function Alternation and Target Form aimed at testing the influence of different morphosyntactic specifications in primes and targets (asymmetric priming), the factor Lexical Repetition targeted the level of representation: conditions with the 'same verb' potentially involve item-specific processing, while the 'different verb' conditions targeted generalised, more abstract representations (i.e., generalised paradigms) via priming of morphosyntactic contexts/features without involvement of the same lexical verb. An example of a full set of conditions for one item is given in Table 1 with the three factors that formed the experimental conditions highlighted in the three rightmost columns.

The use of pronouns (he/she) in prime and target phrases was cross-balanced over all items. In order to reduce item repetition, the 256 critical trials (32 verbs x 8 conditions) were distributed over four different experimental lists according to a Latin square so that each item appeared only twice on each list: once in one of the 'same verb' lexical conditions (i.e., with the same verb in prime and target, rows 1-4 in Table 1) and once in one of the 'different verb' lexical conditions (i.e., with different verbs in prime and target, rows 5-8 in Table 1). The combination of which of the four 'identical' and 'different' lexical conditions of one item appeared in one particular list and their order was completely cross-balanced over items and lists. In sum, each list contained 64 critical prime-target pairs.

In addition, filler phrases were added to each list to balance the number of grammatical and ungrammatical forms, the use of syntactic structures, and the distributional probabilities in the experiment to avoid any bias or strategy in the participants' behaviour. First, 64 filler prime-target pairs were created that completely paralleled the critical items (concerning combinations of participles vs. inflected forms and verb repetition in prime and target), but that were ungrammatical in their target phrases. Ungrammaticality of fillers was achieved by incorrect number and/or person agreement (e.g., *wir LESEN* – "we read"; **wir LIEST* – "*we reads"). Second, 128 filler phrases (64 correct, 64 incorrect) were added that did not appear as pairs (of primes and targets), but that also contained verb forms or participles. Third, 180 filler phrases (90 grammatical, 90 ungrammatical) were added that contained completely different syntactic structures (e.g., *in der historischen Stadt* – "in the historic town"); some also appeared as pairs of prime and target. Ungrammaticality of fillers was again achieved by incorrect number and/or person agreement, or incorrect number and/or gender agreement between nouns and preceding articles or adjectives (e.g., **auf meiner Boot* – "on my [feminine] boat[neuter]").

Overall, grammaticality, syntactic structure, lexical repetition, and structural repetition were completely cross-balanced. Each of the four experimental lists consisted of 500 single judgement tasks (64 prime + 64 target phrases of critical trials, 372 filler phrases).

Procedure

Participants were tested individually. They had to decide whether the word presented in the second step (i.e., the critical word) was a correct (grammatical) continuation of the phrase. They were instructed to respond as fast and accurately as possible. All stimuli were presented electronically using the E-Prime 2.0 software (Schneider et al., 2002).

Primes and target phrases of all critical items and all filler phrases were presented in the same way without indications whether a single judgement task belonged to a prime, target, or filler phrase. A trial containing a target phrase immediately followed the trial containing the corresponding prime phrase: there were no intervening fillers between a prime and a corresponding target. Each trial started with a fixation sign ('*') presented at the centre of the screen for 500ms. Then a phrase was displayed in two stages. In the first stage, all linguistic material preceding the verb or participle was presented, centred on the screen, and printed in black (e.g., *er hat* – "he has"). After 750ms the words disappeared and the second part of the phrase

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Table 1. Examples for experimental conditions.

Prime Phrase			Target Phrase		Experimental Conditions		
						Prime-Target Relation	
					Target Form	Function Alternation	Lexical Repetition
sie 'she'	*BESUCHT* 'visits'	→	*er* 'he'	*BESUCHT* 'visits'	inflected	same	same verb
sie hat 'she has'	*BESUCHT* 'visited'	→	*er* 'he'	*BESUCHT* 'visits'	inflected	changed	same verb
sie hat 'she has'	*BESUCHT* 'visited'	→	*er hat* 'he has'	*BESUCHT* 'visited'	participle	same	same verb
sie 'she'	*BESUCHT* 'visits'	→	*er hat* 'he has'	*BESUCHT* 'visited'	participle	changed	same verb
sie 'she'	*VERFOLGT* 'follows'	→	*er* 'he'	*BESUCHT* 'visits'	inflected	same	diff. verb
sie hat 'she has'	*VERFOLGT* 'followed'	→	*er* 'he'	*BESUCHT* 'visits'	inflected	changed	diff. verb
sie hat 'she has'	*VERFOLGT* 'followed'	→	*er hat* 'he has'	*BESUCHT* 'visited'	participle	same	diff. verb
sie 'she'	*VERFOLGT* 'follows'	→	*er hat* 'he has'	*BESUCHT* 'visited'	participle	changed	diff. verb

(consisting only of the critical word, i.e., the inflected verb or participle, e.g., *BESUCHT* – "visited") was presented in capital letters, in dark green in the same, central position. Participants were instructed to judge whether the second, green-printed part was a grammatical or ungrammatical completion of the phrase by pressing one of two buttons. After the participant's response was recorded or after a maximum duration of 2000ms the word disappeared. Accuracy and latency of responses were measured. The next trial started after an inter-stimulus interval (blank screen) of 600ms. There were three pauses during the experiment at equidistant intervals. Participants could end each of the pauses and resume the experiment individually by pressing the spacebar. At the beginning of the experiment, there was a training block of eighteen trails to familiarise participants with the task. On average, a complete experimental session took 35 minutes.

Each participant was presented with one of the four lists. The order of items on the lists was pseudorandomised for each participant with the following restrictions: no more than five successive trials with the same grammatical status of the phrase (grammatical/ungrammatical) or more than three successive trials with the same grammatical function (inflected verb/participle) were allowed. Additionally, there was a minimum of three intervening filler trials between critical trials, and at least the first two trials after each of the pauses were filler trials.[7]

Data analysis

For all statistical analyses reported in this paper, the statistical software R, version 4.1.2 (R Core Team, 2021) was used. The data were analysed with mixed-effects regression modelling using the R packages *lme4* (D. Bates et al., 2015) and *lmerTest* (Kuznetsova et al., 2017). A maximal model structure was pursued including items and participants as random effects (see Barr et al., 2013). The maximum model included error terms for items and participants with random intercepts and random slopes for all predictor variables and their interactions. If the maximum model did not converge, error terms were stepwise reduced starting with eliminating the highest order interaction till convergence of the resulting model was achieved. Final model structures are reported for each of the analyses below. Significance of fixed effects was evaluated using the R package *lmerTest* (Kuznetsova et al., 2017) with Satterthwaite approximation for degrees of freedom. All bivalent categorical predictor variables were effect-coded (i.e., as -0.5/+0.5). Post-hoc comparisons between multiple conditions were conducted based on the final model's estimated means using the R package *emmeans* (Lenth, 2022) with Tukey adjustment of *p*-values for multiple comparisons.

Raw data of reaction times were first log-transformed to compensate for non-normality. After that, the data were checked for outliers and winsorised with the 1st and 99th percentile as boundaries: for each participant, all data points that fell below the 1st percentile or above the 99^{th} percentile were set to these boundary values instead of excluding them from the analysis (see also Nicklin & Plonsky, 2020).

Results and discussion

Responses to target phrases were analysed only if the corresponding prime phrase was judged correctly leading to the exclusion of 4.92% of the data.

Accuracy

Accuracy for the remaining targets approached ceiling (overall accuracy rate: 96.8%) indicating that participants had no problems performing the task. However, considering the marginal numerical differences between conditions and the very high overall accuracy, a meaningful interpretation is difficult. As their pattern generally complies also with the pattern of results for reaction times, we refrain from reporting the results of the accuracy scores here but refer to the detailed statistical report in Appendix A1.

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Table 2. Experiment 1: Reaction Times to Targets in ms (with SD in brackets and number of observations in square-brackets).

	Lexical Repetition			
	Same verb		Different verbs	
	Inflected	Participle	Inflected	Participle
Same grammatical function	638.8 (168.2) [362]	630.5 (160.0) [367]	688.3 (182.9) [356]	707.2 (165.9) [337]
Changed grammatical function	694.5 (182.6) [358]	640.9 (158.9) [356]	740.5 (192.7) [342]	709.1 (165.5) [347]
Difference same vs. changed	*−55.7*	*−10.4*	*−52.2*	*−1.9*

Reaction times

Latencies to target phrases were analysed only if the target phrase itself and the corresponding prime phrase were responded to correctly (excluding ca. 7.9% of all data points). The results are summarised in Table 2 (see also Figure 1A).

A linear mixed effects model revealed main effects for Target.Form ($F(1, 36.6) = 4.47$, $p = .041$), Function.Alternation ($F(1,71.6) = 37.48$, $p < .001$), and Lexical.Repetition ($F(1, 38.2) = 62.86$, $p < .001$). More importantly, there were significant interactions indicating that the influence of the factor Target.From was moderated both by Function.Alternation ($F(1, 36.8) = 16.56$, $p < .001$), and by Lexical.Repetition ($F(1, 30.6) = 5.32$, $p = .028$) – see Table 3 for details. For further interpretation of these interactions, pairwise comparisons of estimated means were conducted (see Table S3 in supplementary materials). Information about (non-)significance of relevant comparisons between conditions is also added to Figure 1A in terms of p-values.

Results reveal a clear pattern. First, in the conditions with the same lexical verb in prime and target (Figure 1A, left panel), participle targets are primed by inflected verbs (e.g., *er BESUCHT* → *er hat BESUCHT*) to the same extent as in the full-repetition priming (640.9ms vs. 630.5ms, $p = .961$). In contrast, responses to inflected verbs as targets with participle primes (e.g., *er hat BESUCHT* → *er BESUCHT*) are slower and priming is reduced compared to the full-repetition condition (638.8ms vs. 694.5ms, $p < .001$). We thus observe an asymmetric priming pattern with more specific primes (inflected verbs) being better primes than less-specific primes (participles). Second, in the conditions with different lexical verbs in primes and targets (Figure 1A, right panel), a similar pattern of results is observed: when the less specific participles are targets, the more specific inflected forms prime them to the same degree as do participle primes in the repetition condition (709.1ms vs. 707.2ms, $p = .998$). When the more specific inflected forms are targets, facilitation is reduced in the 'different function' condition with the less specific participle primes compared to the full repetition condition with inflected verb primes (740.5ms vs. 688.3ms, $p = .001$).

A significant interaction between Lexical.Repetition and Target.Form also indicates differences between the conditions with and without lexical repetition: participle forms are facilitated even more in conditions with repeated verbs than in conditions with different verbs where only the abstract feature sets overlap between the prime and the target. In conditions without a repeated verb, both participle conditions score in-between the fastest (inflected 'same') and the slowest (inflected 'changed') conditions and do not differ statistically from either of them (all $p > .240$). In contrast, in the conditions when the lexical verb is repeated in prime and target, both participle conditions are significantly faster than the slowest inflected (changed) condition.

In sum, the results of Experiment 1 with native participants reveal an expected asymmetric priming relation: the less specific participles as targets were better primed by the more specific inflected verb forms (inflected verb → participle) than vice versa (participle → inflected verb). This pattern was observed both in the condition with lexical repetition of the verb and across different verbs.

2.2 Experiment 2

The main objectives were the same as in Experiment 1, but we also pursued a fourth objective: a comparison of morphosyntactic feature processing in L2.

Method

Participants

Forty-eight non-native advanced learners of German with Czech as their native language participated (36 female, $M_{age} = 24.9$ years; range 19-39, $SD = 4.5$). Language proficiency of all non-native participants was assessed prior to the experiment with three different measures (a shortened version of the Dialang online test, a shortened version of the Goethe test, and a self-evaluation using a questionnaire). Only participants scoring in the range of B2-C1 level according to the Common European Framework of Reference for Languages (CEFR) in all three tests were allowed to participate in the experiment. Both B2 and C1 levels represent a (pre)advanced proficiency level in L2. Participants received monetary compensation.

Materials, *procedures*, and principles of *data analysis* were identical with those reported for Experiment 1.

Results and discussion

Accuracy

Similar to Experiment 1, overall accuracy was very high (95.9%) indicating that non-native participants had no problems performing the task. A detailed statistical report for error rates is provided in Appendix A1.

Reaction times

Latencies to target phrases were analysed only if the target phrase itself and the corresponding prime phrase were responded to

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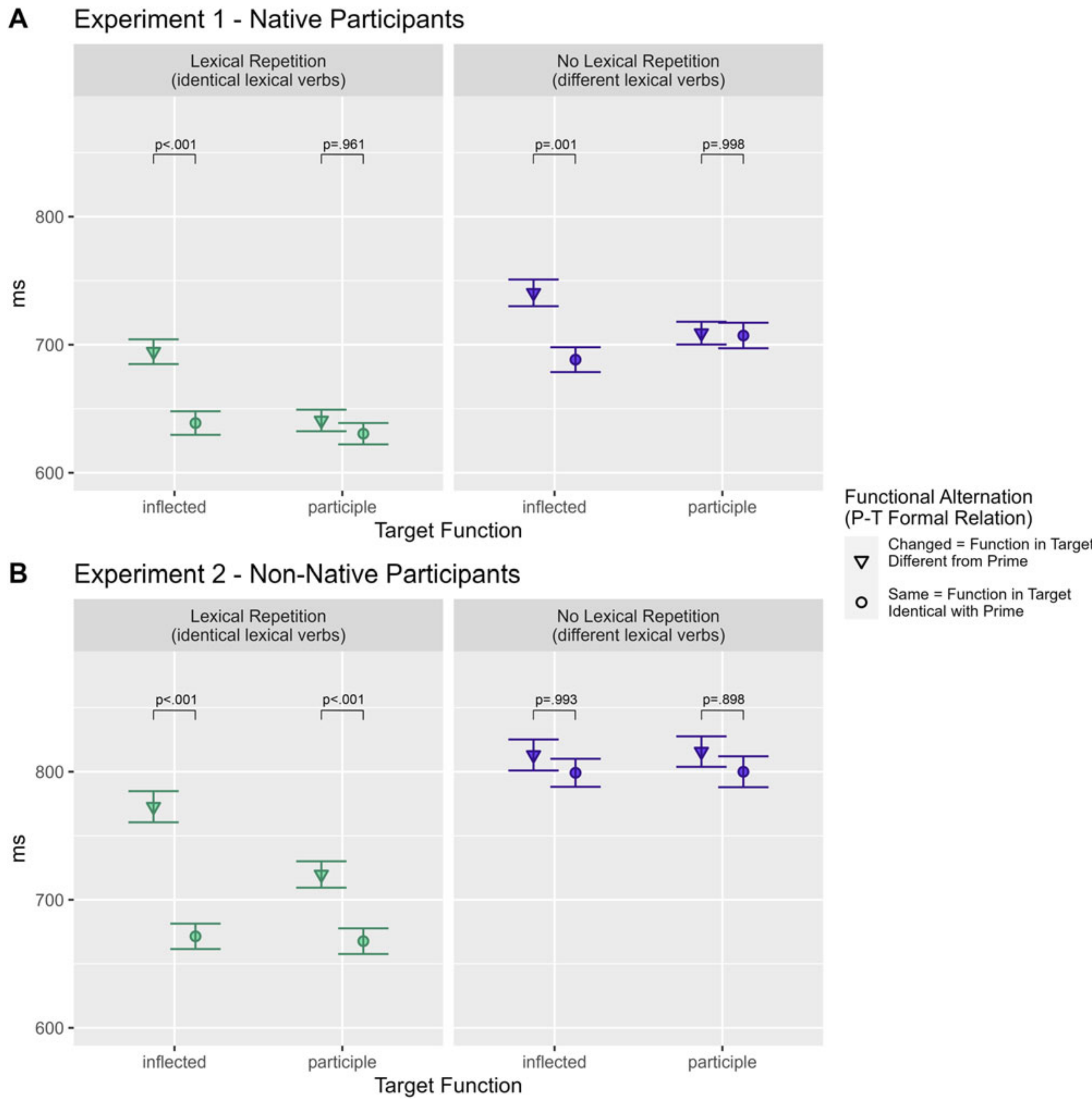

Figure 1. Results of experiments 1 (panel A) & 2 (panel B): mean latencies for critical target words (in milliseconds with error bars).

correctly (excluding ca. 8.7% of all data points). The results are summarised in Table 4 (see also Figure 1B).

Results of the linear mixed effects model ANOVA-table for fixed effects are presented in Table 5.

Beyond significant main effects for Lexical.Repetition (F(1, 42.6) = 159.83, $p < .001$) and Function.Alternation (F(1, 41.0) = 48.69, $p < .001$), there was a significant interaction of Lexical.Repetition and Function.Alternation (F(1, 49.61) = 25.58, $p < .001$) and a marginal interaction of Lexical.Repetition and Target.Form (F(1, 53.8) = 3.59, $p = .063$). Most importantly, and in contrast to Experiment 1, there was a significant higher-order three-way interaction (F (1, 2500.5) = 4.13, $p = .042$). This interaction was further analysed via computing pairwise contrasts (for detailed results see Table S4 in supplementary materials).

The pairwise contrasts revealed that the four conditions with non-identical lexical verbs for L2 participants did not differ from each other at all (all $p>=.898$, see also Figure 1B, right panel). Thus, the statistical analyses provide no indications that the repetition of a function (i.e., of a set of morphosyntactic features associated with the 3rd person singular vs. past participle) in prime and target phrases alone influenced participants' reaction times. In contrast, when the same verb was repeated in prime and target, the pattern of results looks similar (although not identical) to the one observed for L1 participants (see also Figure 1B, left panel): slowest responses were observed to inflected verb targets preceded by participle primes (participle → inflected verb, 772.7ms; all $p \leq .04$). The fastest responses were observed for the identical conditions, i.e., when the same grammatical function

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Table 3. Mixed model ANOVA (type III) table for L1 participants.

Effect	SumSq	NumDF	DenDF	*F* value	Pr(>F)
Lex.Rep	1.971	1	38.2	62.86	<.001
Func.Alt	1.175	1	71.6	37.48	<.001
Target.Form	0.140	1	36.6	4.47	.041
Func.Alt:Target.Form	0.519	1	36.8	16.56	<.001
Lex.Rep:Target.Form	0.167	1	30.6	5.32	.028
Lex.Rep:Func.Alt	0.010	1	30.3	0.334	.568
Lex.Rep:Func.Alt.Target.Form	0.001	1	2497.8	0.02	.890

(and lexical verb) was repeated in prime and target (full repetition priming; participle → participle 667.7ms and inflected verb → inflected verb 671.5ms). However, responses to participles preceded by an inflected verb in the prime (inflected verb → participle, 719.7ms) were significantly slower than full priming conditions (both $p < .001$), though they were still faster than the slowest condition (participle → inflected verb, 772.7ms; $p = .038$).

Experiment 2 revealed that L2 participants showed indications of asymmetric priming in the expected direction. This was, however, only the case when the lexical verb was repeated in prime and target. Moreover, although the more specific inflected form in this condition primed the less specific participle form to some degree (inflected verb → participle), the facilitation was smaller than in the full-repetition condition, which would not be expected (and was not the case in L1), since the set of the morphosyntactic features of the participle is a subset of the inflected form morphosyntactic feature set. In the non-lexical conditions, where only morphosyntactic configurations (or abstract, generalised paradigms) were either identical or different in prime and target, no differences in priming were observed in L2.

2.3 Joint analyses of Experiments 1 and 2

The priming patterns for Experiment 1 and 2 are summarised in Figure 1. In the combined statistical analysis, the between-subject factor Language (L1 vs. L2) was included as a fixed effect in the model.

Results revealed that the factor Language was involved in various significant interactions substantiating the observation that the pattern of priming results was indeed different for native versus non-native participants. Among those interactions, the most relevant are the three-way interactions of Language: Function.Alternation:Target.Form ($p = .047$) and Language: LexicalRepetition:Function.Alternation ($p < .001$). For details of this analysis (mixed model ANOVA table) see Table S5 in Supplementary materials. Thus, in accordance with the visual impression obvious in Figure 1, statistical analysis confirmed that the patterns of results for L1 and L2 participants are in sharp contrast.

Based on all analyses, the most important findings are as follows: in L1, we observed priming between morphosyntactic feature sets using lexically unconditioned regular verb forms with different degrees of morphosyntactic specification. The more specific 3rd person singular forms fully primed the less specific past participle forms, but the less specific participle forms with a smaller morphosyntactic feature set did not fully prime the more specific inflected forms. However, in L2 this (less pronounced) pattern was restricted to the condition in which the lexical verb was repeated. In the condition where only morphosyntactic configurations (i.e., the function of the forms) were repeated and the lexical verb was different, no indication for better priming ability of the morphosyntactically more specific forms could be observed. In contrast to the L1 data, we found no evidence that advanced L2 learners would engage in morphosyntactic processing on a more abstract level of generalised paradigms. Moreover, since the observed effects in the lexical repetition conditions were between formally identical word forms that differed only in their function, we can conclude that morphosyntactic specification is bound to the function of the word forms and not to their surface forms.

Table 4. Experiment 2: Reaction Times to Targets in ms (with SD in brackets and number of observations in square-brackets).

	Lexical Repetition			
	Same verb		Different verbs	
	Inflected	Participle	Inflected	Participle
Same grammatical function	671.5 (189.9) [367]	667.7 (188.0) [352]	799.2 (206.1) [355]	800.0 (224.8) [348]
Changed grammatical function	772.7 (225.6) [345]	719.7 (190.1) [340]	813.1 (224.0) [341]	815.7 (218.3) [337]
Difference same vs. changed	*−101.2*	*−52.0*	*−13.9*	*−15.7*

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Table 5. Mixed model ANOVA (type III) table for L2 participants.

Effect	SumSq	NumDF	DenDF	*F* value	Pr(>F)
Lex.Rep	6.073	1	42.6	159.83	<.001
Func.Alt	1.850	1	41.0	48.69	<.001
Target.Form	0.115	1	33.8	3.03	.091
Func.Alt:Target.Form	0.080	1	58.4	2.11	.152
Lex.Rep:Target.Form	0.137	1	53.8	3.59	.063
Lex.Rep:Func.Alt	0.972	1	49.6	25.58	<.001
Lex.Rep:Func.Alt.Target.Form	0.157	1	2500.5	4.13	.042

3. General discussion

The present study contributes to the line of research investigating differences between L1 and L2 morphosyntactic processing, in particular in retrieval of morphosyntactic feature sets associated with less vs. more specific word forms. Our results agree with the previous findings on (under)specification and expand them in several directions.

3.1 Different levels of abstractions in morphosyntactic processing in L1 and L2

From the theoretical perspective, our results provide further evidence for non-native processing of morphosyntax by L2 learners and show that it operates on a less generalised, less abstract level than L1 processing: while we observed the expected asymmetrical priming effects in both the condition when the lexical verb was repeated and the condition with different verbs in prime and target (i.e., when only the morphosyntactic configurations/functions of the primes and targets were manipulated) in L1, in L2 the priming effects were absent in the latter condition. This difference suggests that L2 grammatical processing is idiosyncratic and bound to individual lexical items since the effect of differently specific grammatical information for participles vs. inflected verbs disappeared when the verb was not repeated in the prime and target.

This finding agrees with accounts such as the DP model and the SSH (Ullman, 2004, 2005, 2020; Clahsen & Felser, 2006, 2018) that highlight the limited ability of L2 learners to process morphosyntax. They can be also interpreted as an instantiation and specification of the models' assumption that L2 grammar processing depends more on the lexicon. In contrast, the grammatical processing in L1 can be viewed as more lexicon-independent with its abstracted combinatorial, hierarchical aspects subserved by the grammatical/procedural system.

The finding can be interpreted from the decompositional perspective as supporting the claim that L2 learners rely more on retrieving whole forms than on decoding of morphological structure of complex words (which requires rule-based, hierarchical processing). This perspective suggests that abstract-level processing in L1 could be due to the independent representation of the suffix *-t* in the lexicon, allowing for independent priming of corresponding feature sets. If L2 learners cannot decompose verb forms into stem and suffix, the whole word form becomes associated with specific morphosyntactic features, hindering lexically independent priming.

However, an alternative interpretation exists. The ability to independently prime abstract morphosyntactic configurations in L1 complies also with Relational Morphology (Jackendoff & Audring, 2020) and other constructionist approaches positing generalized morphosyntactic schemas in the extended lexicon. Such assumptions offer a solid base for explaining observed priming of abstract morphosyntactic configurations in L1. The absence of lexically independent priming in L2 may stem from learners' difficulty in establishing or effectively utilizing such generalized schemas during online processing. Word-based frameworks challenge the dual-route dichotomy of morpheme-based models (see Giraudo & Dal Maso, 2016). However, asymmetrical priming poses a challenge for these approaches, as RM or CxM lacks a straightforward explanation for why the same pair of schemas would prime differently depending on the priming direction.

To account for asymmetric priming, it seems necessary to assume that it is not holistic morphosyntactic representations or schemas that are primed, but that the primed entities are compositional at least in the sense that they are constituted by shared morphosyntactic feature representations and that the overlap between these entities affects the degree of priming. Without aspiring to offer a complete account, we envision these entities as configurations of morphosyntactic features in a network. When retrieving a form, the network of corresponding features is activated. Assuming generic representations of morphosyntactic features (see also E. Bates et al., 1996; Bordag et al., 2006; Riordan et al., 2015; Schriefers, 1993), such arrangement would imply that forms with particular functions activate the same or partially overlapping configurations of features in this (feature)network. Activation of shared parts of the feature network would then enable their priming. This approach offers a potential explanation for both asymmetrical and lexically independent priming of functions in L1.

The absence of morphosyntactic priming without stem repetition in L2 may result from the absence of a generalized morphosyntactic network at the highest, lexeme-independent level. During language development, learners would initially form idiosyncratic morphosyntactic representations based on individual word forms. Fusing related forms into one lexeme creates a generalized morphosyntactic network shared among all forms within that lexeme. At the next generalisation stage, the highest level, a network shared by all lexemes within a (sub)class (e.g., all verbs in German) might emerge in L1, leading to lexeme-independent priming. Its absence in L2 could be due to the inability to use this higher-level abstraction network fully or efficiently during online processing. Alternatively, the original lexeme-based networks may be more accessible or faster to retrieve in L2, while they would become dispensable in the fully developed L1 system once higher-order generalized networks are established and firmly

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integrated into the system. This idea of compromised access to higher-level morphosyntactic representations in L2 aligns conceptually with the SSH assumptions (Clahsen & Felser, 2006, 2018). For Czech learners of German, such implementation might be especially likely, as similar generalisation over all verbal lexemes may not be possible in their L1, since Czech verbs with different specifications for aspect, e.g., differ in how they instantiate tempus (three values with imperfective verbs and two values in perfective verbs[8]).

3.2 Differences in morphosyntactic processing on the lexical level in L1 & L2

Our second important finding demonstrates that L2 processing is not fully native-like at the lexical level either: (under)specification of processed forms is not manifested in the same way as in L1, but the pattern of results seems to approximate the more clear-cut asymmetrical priming profile in L1. This was seen in the fact that, in the lexical conditions, the amount of facilitation for participle targets when they were preceded by inflected verbs did not reach the same degree as in L1: while full priming of the same size as full-repetition priming was observed in L1, in L2 facilitation was larger than in the changed condition with inflected target verbs, but still smaller than full priming in the full-repetition condition when the function and verb were repeated in prime and target.

It is not fully clear how the discussed accounts would explain, beyond general claims, that L2 learners have difficulties with mapping grammatical functions (i.e., appropriate sets of morphosyntactic features) to affixes as proposed also by Veríssimo et al. (2018).

However, the observed L1 vs. L2 difference in the asymmetric pattern in the lexical condition which is less pronounced in L2 than in L1 can be well captured within the framework of the OM (Bordag et al., 2021) and the FLR (Gor et al., 2021) hypothesis. Neither the OM model nor the FLR hypothesis have been elaborated in detail for the area of morphosyntax so far, but its general specification enables us to draw conclusions about this domain, too. Analogously to the mappings between the domains of phonology, orthography, and semantics, they assume fuzzy mapping also between the morphosyntactic and the word form domain as well as within the morphosyntactic domain: the homonymous verbal forms in our experiments need to be linked to two (partially overlapping) sets/networks of morphosyntactic features (one for participles, one for 3rd person singular present tense). If this mapping is weak or imprecise, we would expect weaker priming in conditions where, e.g., full priming would be expected (based on L1) in case of exact and precise retrieval – exactly as seen in the present study.

The OM and the FLR hypothesis further claim that "less distinct boundaries [between fuzzy lexical representations] result in their reduced differentiation from neighbouring representations" (Gor et al., 2021: Introduction). In the morphosyntax domain, this would mean that less distinct boundaries between the morphosyntactic feature sets/networks for the function of participle vs. 3rd person singular would result in their reduced differentiation leading to less pronounced asymmetric priming effects that are based precisely on the difference between the two sets.

The L2 results can be thus seen also as evidence in support of the OM and the FLR in the morphosyntactic domain that has been only rarely directly addressed within these accounts so far (but see Bordag & Opitz, 2022; to some degree Bosch et al., 2019).

3.3 Methodological considerations: presenting words in context

One problem when exploring the processing of morphosyntax by employing differently specific word forms is confounding it with form properties, e.g., frequency effects and formal overlap, possibly affecting the results. In our study we circumvent these problems by employing overtly identical forms whose surface frequency and overlap between prime and target are thus the same, and we varied only the grammatical function of the examined forms. The fact that we still observed the predicted asymmetrical priming effects shows that the source of these effects is not on the formal, but on the functional level and arises from priming between differently specific morphological feature sets associated with the function of the given form.

Contrary to the previous studies that presented isolated word forms and sometimes even isolated bound morphemes, we presented our targets in minimal syntactic contexts disambiguating their function. This seems to be a more reasonable approach that might also be more informative about language processing under natural conditions. When an isolated word form like the adjective *gut-e* ("good") is presented, it is not clear, what its actual function is and which set of morphosyntactic features is processed, as it can be both feminine singular nominative or accusative, or plural (all genders) nominative or accusative, or even a derived noun *der/die/das Gute* ("the good (one)"). We propose that future research on processing of morphosyntactic features (and perhaps research on morphosyntax in general) takes this into account and presents its critical word forms in syntactically unambiguous contexts. Furthermore, processing of isolated word forms could pose specific problems for L2 learners compared to L1 speakers, possibly impacting some differences observed between L1 and L2 learners: L2 learners may fully or partially fail to morphosyntactically process forms that are unnaturally presented in isolation, but might show sensitivity, albeit possibly still limited to morphological processing in syntactic contexts.

4. Conclusions

The present study extends a line of research that investigates the processing of word forms that are differentially specific with respect to their morphosyntactic features. Using a unique design, we could exclude form-related confounds and demonstrate that processing asymmetries between less specific (non-finite participles) and more specific (inflected verbs) forms can be attributed to their functional/morphosyntactic relationship. We also showed that processing asymmetries are not restricted to lexically conditioned stem alternations of irregular verbs, but extend to regular verb morphology. This indicates that regular and irregular verbs share some common processing principles. Importantly, by directly comparing lexically/item-dependent priming with priming of more abstract morphosyntactic configurations across verbs, the present study identifies crucial differences in the processing of morphosyntactic features in L1 and L2. While results imply that in L1 morphosyntactic processing operates on a more abstract level, L2 processing seems to be more bound to specific lexical items. Finally, we demonstrate how our data enhance the empirical foundation of several current models and show how our unique combination of research questions opens new perspectives to the understanding of morphosyntactic processing in L1 and L2.

In future research, investigations should be extended to other linguistic forms and languages. Both experimental (see Smolka & Ravid, 2019; Milin et al., 2017, for overviews) and computational (Günther et al., 2019) evidence suggest that typological differences between languages may result in differences in morphological representation and processing. It needs to be clarified whether or to what degree the present findings are generalisable to other languages and other linguistic domains such as noun inflection. Morphosyntactic processing also needs to be explored from the age of acquisition and language proficiency perspective to better understand the nature of the differences observed for L1 and L2 and the relationship between morphosyntax and the lexicon in general.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S1366728924000282

Data availability statement. The raw data that support the findings of this study as well as the R scripts that were used for the reported analyses are openly available in the Open Science Framework (OSF) at https://osf.io/k3m2z/

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Competing interests. The authors declare none.

Notes

[1] Participle forms are usually introduced together with the perfect tense (around CEFR level A2), and are covered in more detail at levels B1–B2.
[2] Only in the 3rd person, in other persons the person feature is expressed on the auxiliary that is missing in the 3rd person (e.g., *já jsem zpíval* ('I sang') vs. *on zpíval* ('he sang')).
[3] Our contexts are minimum disambiguating contexts, not minimum sentences, i.e., from possibly more than one obligatory complement (like subject and object(s)) only the subject is expressed in the first step of the prime presentation.
[4] A list of all items is provided in Table S2 in the supplementaries.
[5] Frequency classes are based on the frequency of the most common word *der* – 'the'. Frequency class of 12 means, e.g., that der occurs 2^{12} times as often as the words in this particular class. [public access via www.wortschatz.uni-leipzig.de]
[6] Learners (n=28) on the B2 level who did not participate in the experiment rated on a 7-point scale the familiarity of a set of verbs intended for the experiment and less known fillers. Only verbs with a rating of 6 and higher were then used in the experiment.
[7] Randomisation was carried out with the program 'mix' (van Casteren & Davis, 2006).
[8] The synthetic present form has the present tense value/function with imperfective verbs, but future tense value/function with perfective verbs.

References

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of memory and language*, *68*(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Bates, E., Devescovi, A., Hernandez, A., & Pizzamiglio, L. (1996). Gender priming in Italian. *Perception & Psycholinguistics*, *58*(7), 992–1004. https://doi.org/10.3758/BF03206827

Blom, E., Polišenská, D., & Weerman, F. (2006). Effects of age on the acquisition of agreement inflection. *Morphology*, *16*(2), 313–336. https://doi.org/10.1007/s11525-007-9110-1

Booij, G. (2010). *Construction Morphology*. Oxford: Oxford University Press.

Bordag, D., Gor, K., & Opitz, A. (2021). Ontogenesis Model of the L2 Lexical Representation. *Bilingualism: Language and Cognition*, *25*(2), 185–201. https://doi.org/10.1017/S1366728921000250

Bordag, D., Gor, K., & Opitz, A. (2022). Refining Key Concepts of the Ontogenesis Model of the L2 Lexical Representation. *Bilingualism: Language and Cognition*, *25*(2), 236–241. https://doi.org/10.1017/S1366728921000894

Bordag, D., & Opitz, A. (2021). Representation and processing of overtly identical complex forms in L1 and L2: The case of conversion and its 'siblings'. *Studies in Second Language Acquisition*. https://doi.org/10.1017/S0272263121000206

Bordag, D., & Opitz, A. (2022). Employing General Linguistic Knowledge in Incidental Acquisition of Grammatical Properties of New L1 and L2 Lexical Representations: Towards Reducing Fuzziness in the Initial Ontogenetic Stage. *Frontiers in Psychology*, *12*, 768362. https://doi.org/10.3389/fpsyg.2021.768362

Bordag, D., Opitz, A., & Pechmann, T. (2006). Gender processing in first and second languages: The role of noun termination. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*(5), 1090–1101. https://doi.org/10.1037/0278-7393.32.5.1090

Bosch, S., & Clahsen, H. (2016). Accessing morphosyntax in L1 and L2 word recognition: A priming study of inflected German adjectives. *The Mental Lexicon*, *11*(1), 26–54. https://doi.org/10.1075/ml.11.1.02bos

Bosch, S., Krause, H., & Leminen, A. (2017). The time-course of morphosyntactic and semantic priming in late bilinguals: A study of German adjectives. *Bilingualism: Language and Cognition*, *20*(3), 435–456. https://doi.org/10.1017/S1366728916000055

Bosch, S., Veríssimo, J., & Clahsen, H. (2019). Inflectional morphology in bilingual language processing: An age-of-acquisition study. *Language Acquisition*, *26*(3), 339–360. https://doi.org/10.1080/10489223.2019.1570204

Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cogn. Neuropsychol.* *14*, 177–208. https://doi.org/10.1080/026432997381664

Chamoreau, C., & Estrada-Fernández, Z. (Eds.). (2016). *Finiteness and nominalization*. John Benjamins Publishing.

Clahsen, H., Eisenbeiss, S., Hadler, M., & Sonnenstuhl, I. (2001). The mental representation of inflected words: An experimental study of adjectives and verbs in German. *Language*, *77*(3), 510–543. https://www.jstor.org/stable/3086943

Clahsen, H., & Felser, C. (2006). Grammatical processing in language learners. *Applied Psycholinguistics*, *27*(1), 3–42. https://doi.org/10.1017/S0142716406060024

Clahsen, H., & Felser, C. (2018). Some notes on the Shallow Structure Hypothesis. *Studies in Second Language Acquisition*, *40*(3), 693–706. https://doi.org/10.1017/S0272263117000250

Clahsen, H., Felser, C., Neubauer, K., Sato, M., & Silva, R. (2010). Morphological structure in native and nonnative language processing. *Lang. Learn.* *60*, 21–43. https://doi.org/10.1111/j.1467-9922.2009.00550.x

Clahsen, H., Prüfert, P., Eisenbeiss, S., & Cholin, J. (2002). Strong stems in the German mental lexicon: Evidence from child language acquisition and adult processing. In I. Kaufmann & B. Stiebels (Eds.). *More than Words: a Festschrift for Dieter Wunderlich* (pp. 91–112). Akademie-Verlag. https://doi.org/10.1515/9783050081274

Cook, S. V., & Gor, K. (2015). Lexical access in L2: Representational deficit or processing constraint? *The Mental Lexicon*, *10*(2), 247–270. https://doi.org/10.1075/ml.10.2.04coo

Coughlin, C. E., Fiorentino, R., Royle, P., & Steinhauer, K. (2019). Sensitivity to Inflectional Morphology in a Non-native Language: Evidence from ERPs. *Frontiers in Communication*, *4*, 21. https://doi.org/10.3389/fcomm.2019.00021

Coughlin, C. E., & Tremblay, A. (2015). Morphological decomposition in native and non-native French speakers. *Bilingualism: Language and Cognition*, *18*, 524–542. https://doi.org/10.1017/S1366728914000200

Dell, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review*, *93*(3), 283–321. https://doi.org/10.1111/j.0023-8333.2005.00294.x3

Feldman, L. B., Kostić, A., Basnight-Brown, D. M., Durđević, D. F., & Pastizzo, M. J. (2010). Morphological facilitation for regular and irregular verb formations in native and non-native speakers: Little evidence for two distinct mechanisms. *Bilingualism: Language and Cognition*, *13*, 119–135. https://doi.org/10.1017/S1366728909990459

Foote, R. (2017). The storage and processing of morphologically complex words in L2 Spanish. *Studies in Second Language Acquisition*, *39*(4), 735–767. https://doi.org/10.1017/S0272263115000376

Giraudo, H., & Dal Maso, S. (2016). The Salience of Complex Words and Their Parts: Which Comes First?. *Frontiers in Psychology*, *7*, 1778. https://doi.org/10.3389/fpsyg.2016.01778

Gor, K., & Cook, S. V. (2020). A mare in a pub? Nonnative facilitation in phonological priming. *Second Language Research*, *36*(1), 123–140. https://doi.org/10.1177/0267658318769962

Gor, K., Cook, S. V., Bordag, D., Chrabaszcz, A., & Opitz, A. (2021). Fuzzy Lexical Representations in Adult Second Language Speakers. *Frontiers in Psychology*, *12*, 732030. https://doi.org/10.3389/fpsyg.2021.732030

Günther, F., Smolka, E., & Marelli, M. (2019). 'Understanding' differs between English and German: Capturing systematic language differences of complex words. *Cortex*, *116*, 168–175. https://doi.org/10.1016/j.cortex.2018.09.007

Jackendoff, R., & Audring, J. (2020). Relational morphology: A cousin of construction grammar. *Frontiers in Psychology*, *11*, 2241. https://doi.org/10.3389/fpsyg.2020.02241

Jacob, G., Fleischhauer, E., & Clahsen, H. (2013). Allomorphy and affixation in morphological processing: A cross-modal priming study with late bilinguals. *Bilingualism: Language and Cognition*, *16*, 924–933. https://doi.org/10.1017/S1366728913000291

Jacob, G., Heyer, V., & Veríssimo, J. (2018). Aiming at the same target: A masked priming study directly comparing derivation and inflection in the second language. *International Journal of Bilingualism, 22*(6), 619–637. https://doi.org/10.1177%2F1367006916688333

Kirkici, B., & Clahsen, H. (2013). Inflection and derivation in native and non-native language processing: Masked priming experiments on Turkish. *Bilingualism: Language and Cognition*, *16* (4), 1–16. https://doi.org/10.1017/S1366728912000648

Krause, H., Bosch, S., & Clahsen, H. (2015). Morphosyntax in the bilingual mental lexicon: An experimental study of strong stems in German. *Studies in Second Language Acquisition*, *37*(4), 597–621. https://doi.org/10.1017/S0272263114000564

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. (2017). lmerTest Package: Tests in Linear Mixed Effects Models. *Journal of Statistical Software*, *82*(13), 1–26. https://doi.org/10.18637/jss.v082.i13

Leminen, A., & Clahsen, H. (2014). Brain potentials to inflected adjectives: Beyond storage and decomposition. *Brain Research*, *1543*, 223–234. https://doi.org/10.1016/j.brainres.2013.10.038

Lenth, R. V. (2022). Emmeans: Estimated Marginal Means, aka Least-Squares Means. R package version: 1.7.2. https://CRAN.R-project.org/package=emmeans

Levelt, W. J., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and brain sciences*, *22*(1), 1–38. https://doi.org/10.1017/S0140525X99001776

Milin, P., Smolka, E., & Feldman, L. B. (2017). Models of lexical access and morphological processing. In E. M. Fernández & H. Smith Cairns (Eds.), *The Handbook of Psycholinguistics* (pp. 240–268). Wiley. https://doi.org/10.1002/9781118829516.ch11

Neubauer, K., & Clahsen, H. (2009). Decomposition of inflected words in a second language: An experimental study of German participles. *Studies in Second Language Acquisition*, *31*(3), 403–435. https://doi.org/10.1017/S0272263109090354

Nicklin, C., & Plonsky, L. (2020). Outliers in L2 research in applied linguistics: A synthesis and data re-analysis. *Annual Review of Applied Linguistics*, *40*, 26–55. https://doi.org/10.1017/S0267190520000057

Opitz, A., Bordag, D., & Furgoni, A. (2022). Mental Representation of Word Family Structure: The Case of German Infinitives, Conversion Nouns and Other Morphologically Related Forms. *Frontiers in Psychology*, *13*, 910849. https://doi.org/10.3389/fpsyg.2022.910849

Opitz, A., Regel, S., Müller, G., & Friederici, A. D. (2013). Neurophysiological evidence for morphological underspecification in German strong adjective inflection. *Language*, *89*(2), 231–264. https://www.jstor.org/stable/24671861

Pinker, S. (2009). *Language learnability and language development: With new commentary by the author*. Harvard University Press.

R Core Team (2021). R: A Language and Environment for Statistical Computing. Version 4.1.2. R Foundation for Statistical Computing.

Audring, J. (2019). Mothers or sisters? The encoding of morphological knowledge. *Word Structure*, *12*(3), 274–296.

Regel, S., Opitz, A., Müller, G., & Friederici, A. D. (2015). The past tense debate revisited: Electrophysiological evidence for subregularities of irregular verb inflection. *Journal of Cognitive Neuroscience*, *27*(9), 1870–1885. https://doi.org/10.1162/jocn_a_00818

Riordan, B., Dye, M., & Jones, M. N. (2015). Grammatical number processing and anticipatory eye-movements are not tightly coordinated in English spoken language comprehension. *Frontiers in Psychology*, *6*, 590. https://doi.org/10.3389/fpsyg.2015.00590

Roelofs, A., Meyer, A. S., & Levelt, W. J. M. (1998). A case for the lemma/lexeme distinction in models of speaking: Comment on Caramazza and Miozzo (1997). *Cognition*, *69*(2), 219–230. https://doi.org/10.1016/S0010-0277(98)00056-0

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-prime (version 2.0)*. Psychology Software Tools Inc. https://pstnet.com/products/e-prime

Schriefers, H. (1993). Syntactic processes in the production of noun phrases. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*(4), 841–850. https://doi.org/10.1037/0278-7393.19.4.841

Schriefers, H., Friederici, A. D., & Graetz, P. (1992). Inflectional and derivational morphology in the mental lexicon: Symmetries and asymmetries in repetition priming. *The Quarterly Journal of Experimental Psychology*, *44*(2), 373–390. https://doi.org/10.1080/02724989243000073

Silva, R., & Clahsen, H. (2008). Morphologically Complex Words in L1 and L2 Processing: Evidence from Masked Priming Experiments in English. *Bilingualism: Language and Cognition*, *11*(2), 245–260.

Smolka, E., & Ravid, D. (2019). What is a verb? Linguistic, psycholinguistic and developmental perspectives on verbs in Germanic and Semitic languages. *The Mental Lexicon*, *14*(2), 169–188. https://doi.org/10.1075/ml.00003.int

Ullman, M. T. (2004). Contributions of memory circuits to language: The declarative/procedural model. *Cognition*, *92*(1-2), 231–270. https://doi.org/10.1016/j.cognition.2003.10.008

Ullman, M. T. (2005). A cognitive neuroscience perspective on second language acquisition: The declarative/procedural model. In C. Sanz (Ed.), *Mind and Context in Adult Second Language Acquisition: Methods, Theory, and Practice* (pp. 141–178). Georgetown University Press.

Ullman, M. T. (2020). The declarative/procedural model: A neurobiologically motivated theory of first and second language 1. In *Theories in second language acquisition* (pp. 128-161). Routledge.

van Casteren, M., & Davis, M. H. (2006). Mix, a program for pseudorandomization. *Behavior Research Methods*, *38*(4), 584–589. https://doi.org/10.3758/bf03193889

Veríssimo, J., Heyer, V., Jacob, G., & Clahsen, H. (2018). Selective effects of age of acquisition on morphological priming: Evidence for a sensitive period. *Language Acquisition*, *25*(3), 315–326. https://doi.org/10.1080/10489223.2017.1346104

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