The role of case marking and word order in cross-linguistic structural priming in late L2 acquisition

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Abstract

Several studies found cross-linguistic structural priming with various language combinations. Here, we investigated the role of two important domains of language variation: case marking and word order, for transitive and ditransitive structures. We varied these features in an artificial language learning paradigm, using three different artificial language versions in a between-subjects design. Priming was assessed between Dutch (no overt case marking, SVO word order) and a) an SVO order version, b) a case marking version, and c) an SOV order version. Similar within-language and cross-linguistic priming was found in all versions for transitives, indicating that cross-linguistic structural priming was not hindered. In contrast, for ditransitives we found similar within-language priming for all versions, but no cross-linguistic priming. The finding that cross-linguistic priming is possible between languages that vary in morphological marking or word order, is compatible with studies showing cross-linguistic priming between natural languages that differ on these dimensions.

Keywords: artificial language learning, structural priming, sentence production, syntactic processing

During conversations, speakers often tend to align with their interlocutors. For instance, after hearing a passive sentence, such as “the mouse is chased by the cat”, you will be more likely to use a passive sentence yourself in your following utterance than after hearing an active sentence, such as “the cat chases the mouse”. The phenomenon in which the processing of a structure is affected by the previously experienced structure, is often referred to as *structural priming* (Bock, 1986) and has been widely investigated with a variety of tasks and structures (see Mahowald, James, Futrell, & Gibson, 2016, for an overview of studies). Structural priming in production is investigated by means of sentence completion tasks, where subjects first read a sentence and then complete the following one, or dialogue tasks, where a subject and a confederate take turns to describe pictures. Studies using these and other tasks have shown that structural priming is rather abstract (e.g., Bock, 1986; Bock & Loebell, 1990) and does not depend on prosodic, lexical, or semantic similarity, although effects tend to be larger when there is lexical overlap (i.e. the so-called *lexical boost effect*, Pickering & Branigan, 1998), or semantic overlap (Cleland & Pickering, 2003). Moreover, structural priming is not limited to monolingual situations, but can also take place between languages (Hartsuiker, Pickering, & Veltkamp, 2004). When the same action is involved, cross-linguistic priming effects show a translation equivalent boost, although this effect tends to be smaller than the lexical boost (Schoonbaert, Hartsuiker, & Pickering, 2007).

Several studies found cross-linguistic priming in the production of syntactic structures with a wide variety of language combinations and structures – in particular transitives and ditransitives – (see Van Gompel & Arai, 2018, for a recent review), including German-English ditransitives (Flett, Branigan, & Pickering, 2012; Loebell & Bock, 2003; Hartsuiker, Beerts, Loncke, Desmet, & Bernolet, 2016), Chinese-Cantonese ditransitives (Cai, Pickering, Yan, & Branigan, 2011), Greek-English ditransitives (Salamoura & Williams, 2007), English-Chinese transitives (Chen, Jia, Wang, Dunlap, & Shin, 2013), Polish-English transitives (Fleischer, Pickering, & McLean, 2012), Dutch-English relative clause attachment (Desmet & Declercq, 2006), and Dutch-English genitives (Bernolet, Hartsuiker, & Pickering, 2012; 2013). It has been argued that structural priming between languages reflects the sharing of syntactic representations between prime and target language, which led to the idea that bilinguals share syntax between their languages (i.e. the shared syntax account, Hartsuiker, Pickering, & Veltkamp, 2004). In their developmental account, Hartsuiker & Bernolet (2017) proposed that proficiency might play a crucial role in this sharing in the sense that representations evolve gradually from being item- and language-specific (within verbs) to more abstract (across verbs and languages). Indeed, several studies found larger between-language priming for high-proficient vs. low-proficient bilinguals (e.g., Bernolet et al., 2013; Kim & McDonough, 2008; Schoonbaert et al., 2007), indicating that their syntactic representations are more abstract (i.e., less language-dependent).

Another condition for the sharing of syntax, is that structures need to be similar enough in both languages (Hartsuiker & Bernolet, 2017). But what is similar *enough*? Until now, the majority of studies have tested priming between languages that are typologically very closely related. Exceptions to this are studies investigating Polish-English priming (Fleischer et al., 2012), Greek-English priming (Salamoura & Williams, 2007), Chinese-English priming (Chen et al., 2013), and Korean-English priming (Hwang, Shin, & Hartsuiker, 2018; Shin & Christianson, 2009; Song & Do, 2018). It has to be noted, though, that even languages that are closely related often differ on some dimensions. For instance, the morphology of S-genitives is considerably different in Dutch and English (e.g., "the witch's ball" vs. "de heks haar bal"), but nevertheless there is priming between these structures. Still, the close link between such languages might play a facilitating role in the merging of their structures. Because of the limited number of studies exploring structural priming between languages from different language families or with a different typology, it remains unclear whether structures of these languages can be merged easily into one representation that is shared across languages.

In this article, we report a study that investigated priming effects in transitive and ditransitive sentences, focusing on two important domains of language variation that might affect priming: case marking and word order. Both features have a clear impact on the surface structure of sentences, and as a result, higher levels of abstraction are required to share the syntactic representations of sentences that differ on one of these dimensions. In other words, the syntactic representations have to be flexible enough to allow for differences in both morphological realization and word order. Previous studies investigating structural priming between languages with case marking (e.g., German, Polish, Greek) and languages without case marking (e.g., English, Dutch[1]) found that the presence of case marking did not hinder cross-linguistic priming (Fleischer et al., 2012; Flett et al., 2012; Hartsuiker et al., 2016; Loebell & Bock, 2003; Salamoura & Williams, 2007). In contrast, when the word order was different, several studies failed to find priming between languages in production (Bernolet, Hartsuiker, & Pickering, 2007; Jacob, Katsika, Family, & Allen, 2017; Loebell & Bock, 2003) and comprehension (Kidd, Tennant, & Nitschke, 2005). Hence, it seems that differences in case marking do not affect priming, whereas word order differences do. This shows that bilinguals are able to make an abstraction of present/absent case marking, but not necessarily of different word orders.

However, there are studies that found priming between Dutch medial by-phrase passives, for instance, “de clown (= subject) wordt (= auxiliary) door de bokser (= by-phrase) neergeschoten (= main verb)”, and English final by-phrase passives, for instance, “the clown (= subject) is (= auxiliary) shot (= main verb) by the boxer (by-phrase)” in production (Bernolet, Hartsuiker, & Pickering, 2009) and between German medial by-phrase passives and English final by-phrase passives in comprehension (Weber & Indefrey, 2009). Also other recent studies investigating priming between Chinese and English (Chen et al., 2013) and between Korean and English (Hwang et al., 2018; Shin & Christianson, 2009; Song & Do, 2018) did find structural priming across these languages, despite their different word order. In addition, as Van Gompel and Arai (2018) pointed out, there might be some issues with some of the studies that did not find priming with a different word order. For instance, in their seminal study investigating priming of passives between German (medial by-phrase) and English (final by-phrase), Loebell and Bock (2003) did not only fail to find priming between languages, but also within languages, whereas within-language priming is considered to be a robust phenomenon (Bock, 1986; see Mahowald et al., 2016; Pickering & Ferreira, 2008, for an overview). Thus, it seems that in some cases bilinguals are able to share syntactic structures across languages, despite clear word order differences.

The sharing of syntax between languages might occur independently for different structures throughout acquisition. For instance, the sharing of transitive structures across two languages does not mean that ditransitive structures are also shared between those languages. Evidence for this comes from a recent study that used an artificial language learning paradigm (cf. Wonnacott, Newport, & Tanenhaus, 2008) to investigate structural priming in spoken sentence production between a natural language (Dutch) and an artificial language (Muylle, Bernolet, & Hartsuiker, submitted). The artificial language – baptized "PP02" – consisted of intransitive, transitive, and ditransitive sentence structures. Crucially, the transitive and ditransitive sentences could be formulated in two alternative ways: active vs. passive and double-object (DO) dative vs. prepositional-object (PO) dative respectively. The intransitives acted as filler sentences. Native Dutch speakers (with English and French as L2) acquired the artificial language in the lab during five sessions by means of a battery of tasks. Each session ended with a sentence priming task, in which participants first evaluated whether a sentence matched an action (depicted in a movie clip), and then described a new movie clip with a sentence. Primes could be in Dutch or PP02, whereas target sentences could be in the same language or in the other language, involving the same action (i.e., priming with repeated/translation equivalent verbs, which we will refer to as *related* priming) or a different action (i.e., *unrelated* priming). There was structural priming between Dutch and PP02 in both directions already at the end of the first session, but only for the transitive sentences. For the ditransitives, priming within PP02 was found on the first day of learning, but cross-linguistic priming of ditransitives emerged only from the third session onwards. These findings are in line with a prediction of Hartsuiker and Bernolet's (2017) developmental account, namely that within-language priming emerges before between-language priming. Moreover, the results suggest that the sharing of syntactic representations occurs independently for different structures. One reason for the later onset of cross-linguistic priming for ditransitives might be that the higher complexity of this structure (in terms of constituents) delays the integration of the artificial language with the L1 syntax. However, further studies are necessary to confirm the existence of such delay during L2 acquisition.

In the current study, we used an adapted version of the PP02 learning paradigm to help to better understand the role of case marking and word order in cross-linguistic priming. Indeed, an artificial language has the advantage that specific language features, such as case marking or word order, can be manipulated, while controlling for all other factors that might influence structural priming across languages. Again, Dutch was taken as native language of the participants. Originally, Dutch had overt case markers as in German, but these are gone in modern Dutch (Weerman, 2003). Now, there are some leftovers in fixed expressions (e.g., "de dingen des levens" [the things (of) the_GEN life_GEN]) and for personal pronouns, a different form is used when it appears as subject (e.g., "hij" [he], "zij" [she]) compared to (in)direct object or after prepositions (e.g., "hem" [him], "haar" [her]), just as in English. Additionally, Dutch main clauses have SVO word order, whereas subordinate clauses have SOV word order.

Despite the fact that Dutch speakers might be somewhat familiar with both case marking and SOV word order, most of them do not realize that there are remains of case marking and word order differences in Dutch. In order to investigate the role of case marking and word order in cross-linguistic priming, we adapted the PP02 paradigm to a single session and created new PP02 grammars that either had overt case marking or SOV word order. If the priming pattern in one of these PP02 versions would be significantly different from that of a baseline PP02 version, this difference can only be caused by the presence of these linguistic features. Moreover, different patterns may be observed for transitives and ditransitives, given that in Muylle, Bernolet et al.'s (submitted) study the latter required more time to become shared across languages. In sum, the current study aims to find an answer to the following research question: Do differences in case marking and word order play a role in the emergence of shared syntactic representations between languages?

Experiment

To test the role of case marking and word order independently, three new versions of PP02 were created: a) a *baseline* version, which had no overt case marking and the same word order as in Dutch, b) a *case marking* version, which had the same word order as Dutch, but in contrast to Dutch had explicit case markers, and c) an *SOV* version, which had no case marking, but a different word order in the main clause compared to Dutch. The case marking version had four overt case markers: a) *–ni*, designating the patient in an active construction (i.e., accusative), b) *–da*, indicating the recipient when it is mentioned before the object (as in a DO-dative), c) *–bo*, marking the recipient when it is mentioned after the object (as in a PO-dative) and d) *–ka*, the agent in a passive construction. For the subject of the sentence (i.e., nominative) there was no overt case marker. Apart from these grammatical differences, the languages were identical (also in terms of exposure). In Table 1, examples can be found for each structure in each PP02 version. We taught 144 young adults one of these versions by means of the PP02 learning paradigm, but only a single session was administered. At the end of the session, structural priming was assessed in different conditions by manipulating the relationship between prime and target in a way that the prime and target language could be either PP02 or Dutch and the prime and target verb could be related (same verb or translation equivalent) or unrelated (different verb). This manipulation resulted in eight priming conditions for each PP02 version: a) related PP02-PP02, b) unrelated PP02-PP02, c) related Dutch-PP02, d) unrelated Dutch-PP02, e) related Dutch-Dutch, f) unrelated Dutch-Dutch, g) related PP02-Dutch, and h) unrelated PP02-Dutch.

Table 1. *Examples of each structure for each PP02 version.*

	Baseline	Case marking	SOV	Dutch
intransitive	Dettus jaltsi *Clown waves*	Dettus jaltsi *Clown_NOM waves*	Dettus jaltsi *Clown waves*	De clown zwaait *The clown waves*
active	Dettus zwifsi fuipam *Clown kisses cook*	Dettus zwifsi fuipam-ni *Clown_NOM kisses cook_ACC*	Dettus fuipam zwifsi *Clown cook kisses*	De clown kust de kok *The clown kisses the cook*
passive	Fuipam nast zwifo ka dettus *Cook is kissed by clown*	Fuipam nast zwifo dettus-ka *Cook_NOM is kissed clown-by*	Fuipam ka dettus nast zwifo *Cook by clown is kissed*	De kok wordt gekust door de clown *The cook is kissed by the clown*
DO-dative	Dettus heufsi fuipam sifuul *Clown gives cook hat*	Dettus heufsi fuipam-da sifuul-ni *Clown_NOM gives cook_DAT hat_ACC*	Dettus fuipam sifuul heufsi *Clown cook hat gives*	De clown geeft de kok de hoed *The clown gives the cook the hat*
PO-dative	Dettus heufsi sifuul bo fuipam *Clown, gives hat to cook*	Dettus heufsi sifuul-ni fuipam-bo *Clown_NOM gives hat_ACC cook-to*	Dettus sifuul bo fuipam heufsi *Clown hat to cook gives*	De clown geeft de hoed aan de kok *The clown gives the hat to the cook.*

Methods

Participants. We tested 144 university students (35 males and 109 females; age: *M*= 21.2, *SD*= 4.64). They received either 20 Euro or a course credit and 10 Euro in exchange for participation. All of the participants were native speakers of Dutch exclusively. Most of them had French and English as second languages. They were randomly assigned to the three PP02 versions (i.e., 48 participants for each version). The sample size was determined based on the following considerations: a) because we used a crossed design across participants (i.e., each target had to appear in each priming condition), the sample size had to be a multiple of 16, and b) given the between-subject design, we need sample sizes that are large enough, but still feasible.

Materials & design. The materials were a subset of the stimuli that were used in Muylle, Bernolet, et al. (submitted). Also here, the 3 second movie clips, consisting of short animated transitive, intransitive, and ditransitive actions, were taken from the normed stimulus set provided by Muylle, Wegner, Bernolet, and Hartsuiker (submitted). For the new PP02 versions, the sentences were recorded using Audacity® software (Audacity Team, 2019) in a sound isolating environment by the same speaker. Given that there was less time to acquire the language than in the previous study (where learning was spread over five sessions), participants learned only 12 nouns (of which ten referred to human figures, e.g., *cook, waitress*, and two to objects, i.e. *ball* and *hat*) and six verbs (two intransitives, two transitives, and two ditransitives). An overview of the vocabulary that was used can be found in Appendix S1 (Supporting Information online). For each participant, two verbs were randomly drawn from a set of three possible verbs for both transitives and ditransitives to ensure that all verb combinations were equally distributed across participants.

Experimental tasks. The experiment was programmed in PsychoPy2 Coder (v1.85.6; Peirce, 2009) and consisted of five consecutive blocks in which the participants acquired PP02. The first block was a *vocabulary learning block* (96 trials), in which participants learned the association between pictures of the human figures and objects and their names in PP02. Next, in the *sentence exposure block* (30 trials), they repeated sentences in PP02 describing actions depicted in short action movie clips. The *matching block* (50 trials) assessed the comprehension of PP02 sentences by giving the participants one sentence and two movie clips from which they selected the one that matched the sentence. Half of the trials tested for vocabulary (i.e., the clips differed regarding either one of the human figures, the object, or the action) and the other half for structure (i.e., the clips had a reverse agent and patient/indirect object). In the *sentence production block* (20 trials), participants described movie clips with a PP02 sentence and received feedback by hearing and seeing the correct sentence afterwards. Finally, in the *priming block* (160 trials), a movie clip appeared with the prime sentence and the participants judged whether the sentence matched the clip, after which a new clip appeared that they described in either PP02 or Dutch, depending on a visual cue. This block had a 2 (active vs. passive, or DO vs. PO) x 2 (related vs. unrelated) x 2 (PP02 vs. Dutch prime) x 2 (PP02 vs. Dutch target) factorial design. All spoken responses were recorded in Audacity and there was no time restriction on the responses.

Control tasks. Apart from the PP02 learning tasks, the participants performed a number of control tasks to control for some important group differences: a) the forward and backward digit span task (WAIS-IV subtests; Wechsler, 2008) to measure working memory (WM) capacity, and b) the online version of the LexTALE Dutch (www.lextale.com; Lemhöfer & Broersma, 2012) to measure Dutch language proficiency. In addition, participants completed a language background questionnaire in which they indicated the age at which they started to learn French and English, and rated their proficiency on a 7-point Likert scale in Dutch, English, and French for reading, listening, speaking, and writing. They were also asked to write down which other languages they knew and to which extent they had experience with case marking languages, such as German and Latin.

Procedure. The total duration of the experiment ranged between 1.5 and 2 hours. Before coming to the lab, the students were asked to fill in the language background questionnaire. This was done in order to prevent simultaneous bilinguals from taking part in the study, because we cannot control for influences of other native languages that might have other linguistic features. At the start of the session, the participants sat down in front of a 24-inch computer screen that was connected to a laptop with AZERTY keyboard, and signed the informed consent. Then, the LexTALE Dutch, the forward digit span, and backward digit span tasks were administered consecutively. Next, the participants received a Sennheiser HD 215 headphone and the recording in Audacity started. After reading the instructions, in which they were told that they would learn an artificial language by means of pictures and action movies, each participant sequentially completed the five PP02 learning blocks. In all these blocks, the word and sentence stimuli were simultaneously provided in the spoken (i.e. through the headphone) and written modality. With the exception of the matching block, all pictures and movie clips appeared in the center of the screen on a grey background and the text was presented at the bottom of the screen in black (font: Courier New, bold; height: 62 px).

Vocabulary learning block. In this block, pictures of human figures and objects were presented together with the PP02 word. At a picture's first presentation, the participant was asked to repeat the word underneath it aloud and press space to continue to the next picture. All following times that the picture was presented (eight times in total), it came without the word and the subjects were asked to produce the word themselves, after which they could press the spacebar to receive the correct response.

Sentence exposure block. Here, participants first heard and saw a verb in the middle of the screen, after which a movie clip played along with a written sentence that described the depicted action. The written sentence appeared below the clip. Participants were simply instructed to repeat this sentence aloud and press the spacebar to continue with the next trial.

Matching block. Each trial in this block started with two movie clips appearing respectively on the left and right side of the screen. The left clip played first, directly followed by the right one, ending in a still. After this, a fixation cross appeared centrally between the two movie stills and a sentence was visually displayed underneath, together with the audio. When the audio stopped, participants were asked to decide which movie clip matched the sentence by pressing ‘Q’ for the left clip or ‘M’ for the right clip. The correct clip played again after the button press together with the audio. Now, participants were asked to repeat the sentence aloud and press the spacebar when finished, in order to continue with the next trial.

Sentence production block. Trials in this block started with a movie clip and participants were asked to formulate a sentence in PP02 that described the depicted action. Feedback was provided by the experimenter through a Cedrus RB-730 response box that was connected to the laptop via a long USB cable. In the case of an active or DO response, the experimenter pressed the left button in order to present the correct active or DO sentence (both in the written and auditory modalities), and in the case of a passive or PO response, she pressed the right button for the correct passive or PO sentence. When the response could not be categorized as one of these responses, the experimenter pressed the middle button to randomly pick one of both structures. For the intransitives, there was only one possibility, hence all buttons activated the same sentence. Once the feedback audio stopped playing, the next trial started.

Priming block. In the final block, participants first saw a movie clip accompanied with a sentence and indicated whether the sentence was a correct description of the clip by pressing

'Q' when correct or 'M' when wrong. Next, they saw a new clip, which they were instructed to describe in PP02, when the cue 'AT' (Dutch abbreviation for artificial language) appeared below the clip, and in Dutch, when 'NL' (Dutch abbreviation for 'Nederlands' [Dutch]) appeared below the clip. They pressed the spacebar when finished in order to continue to the next trial.

After completion of the priming block, participants were asked to write down their guess about the goal of the experiment. When this was done, they received the debriefing of the experiment, and answered two final questions: a) whether they noticed that they were sometimes inclined to repeat the structure of the prime sentence (yes/no), and b) if yes, whether they then consciously responded with the other structure (never-rarely-sometimes-often-always). Once these were completed, the experiment was finished.

Coding of responses. For the responses in the production and priming block, transitive sentences were either coded as *active*, *passive*, or *other* and ditransitive sentences as *DO*, *PO*, or *other*. Responses were not required to be entirely correct in order to be assigned to a structure category, as long as all constituents were present (regardless of whether the correct vocabulary, case marker, or preposition was used).

For the coding scheme, thematic roles were not taken into account. Hence, errors in which agent and indirect object were switched did not affect the classification of the ditransitive structure, especially because these roles were often confused in the production of sentences with the verb *dwok* (English: *sell*, which could be confounded with *buy*). Similarly, switching agent and patient in an active structure would still be coded as *active* and vice versa for passives. Datives in the baseline and SOV version were coded as PO whenever a preposition was present, and otherwise as DO. In the case marking version, thematic order determined categorization as PO or DO (because there are no prepositions), unless the case marker *–bo*

(PO case marker) or *–da* (DO case marker) was used (hence if *–bo* was present, the sentence was coded as PO and if *–da* was present as DO). A similar strategy was used for the passive case marker *–ka* on the last word in transitives, which was coded as *passive* (see Appendix S2 in the Supporting Information online, for examples).

Furthermore, when a response was formulated in the wrong target language, it was coded as *other* response. The use of alternative verbs in Dutch was only allowed if the alternative verb had the same valency as the intended target verb; using the transitive verb *doodschieten* [to shoot] instead of *neerschieten* [to shoot down] was allowed, as both verbs lead to transitive target sentences; using the ditransitive verb *geven* [to give] instead of the transitive verb *kussen* [to kiss] was not allowed, as the former verb leads to a ditransitive target sentence (X gives Y a kiss), while the intended target structure is transitive. None of the *other* responses were taken into account for analysis (3.3% of all responses, 765 in total), mainly because in most cases the participant used the wrong target language (Dutch was more often replaced with PP02 than vice versa).

Results

All data and scripts are available on the Open Science Framework (link: https://osf.io/vdnb9).

Control tasks and PP02 accuracy. Because of the between-subjects design, the three experimental groups were compared on the control measures and some additional subject variables, such as age and gender, in order to find out whether differences between groups could be due to differences in the samples. An overview of these comparisons can be found in Table 2. All data were analyzed in R (R Core Team, 2016). One-way ANOVA tests showed that there were no significant differences between the groups, except for PP02 accuracy ($F_{(2,141)}$

= 13.78, $p < .001$). The participant's accuracy score was calculated as the proportion of correct trials for a) the eighth (final) presentation of the nouns in the vocabulary learning task, b) the matching task, c) the production task, d) the matching task in the priming block (only for PP02 primes), and e) target sentences in the priming block (only for PP02 targets); the score was the average of a) through e), weighted by the number of trials. Tukey's HSD test revealed significantly lower accuracy scores in the case marking PP02 version compared to the other two versions (baseline $p < .001$; SOV $p = .008$).

Case marking experience was scored as a binary variable, based on information from the language background questionnaire. Participants who had reasonable experience with case marking languages (i.e., courses of more than 1 hour per week for more than 1 year) were coded as '1' and the others as '0'. To test the effect of case marking experience on accuracy in the different PP02 versions, a two-way ANOVA test was administered, resulting in a significant interaction between case marking experience and PP02 version ($F_{(2,141)} = 3.21$, $p = .04$). Post-hoc pairwise contrasts with Bonferroni correction using the phia package in R (De Rosario-Martinez, 2015) revealed that Accuracy scores were significantly lower for participants without case marking experience (M= 0.66, SD= 0.10) than for those with case marking experience (M= 0.76, SD= 0.12) in the case marking PP02 version ($F_{(1,142)} = 7.99$, $p = .02$), but not in the other versions. However, there were few participants in the groups without compared to those who had case marking experience.

Table 2. *Between group comparisons of some subject variables.*

	Baseline *M (SD)*	Case marking *M (SD)*	SOV *M (SD)*
Age	21.3 (2.82)	22.0 (5.18)	20.2 (5.38)
Sex (N of females)	33	37	39
LexTALE Dutch	89.3 (7.01)	89.2 (6.92)	88.5 (6.26)
forward digit span	6.4 (1.25)	6.5 (1.03)	6.1 (1.09)
backward digit span	4.8 (1.09)	5.3 (1.11)	5.0 (0.99)
case marking experience (N)	35	36	37
awareness of goal (N)[2]	8	8	5
PP02 accuracy	0.84 (0.09)	0.73 (0.12)	0.80 (0.10)

Structural preferences. A table with the exact number of responses for each structure that has been produced during the priming block can be found in Appendix S3 (in the Supporting Information online). When the action was transitive, the proportion of active responses out of all actives and passives was 87% in the baseline PP02 version, 79% in the case marking version, and 83% in the SOV version. For the Dutch sentences, this was 76% in the baseline version, 73% in the case marking version, and 75% in the SOV version. In the case of ditransitive actions, a PO sentence was the preferred structure for PP02 targets in the baseline (70%) and case marking version (72%), but not in the SOV version (35%). This difference was not present in Dutch targets (baseline: 77%, case marking: 79%, SOV: 77%).

Priming effects. The priming effect for the transitives was calculated as the difference between the proportion of active answers after an active prime and the proportion of active answers after a passive prime. For the ditransitives, this was the difference between the proportion PO answers after a PO prime and the proportion of PO answers after a DO prime. In Figure 1, priming effects are reported for each priming condition in each PP02 version.

<Insert Figure 1 around here>

Generalized linear mixed effect models with the logit link function were fitted separately for transitive (outcome variable: active answer) and ditransitive sentences (outcome variable: PO answer) using the lme4 package (Bates, Maechler, Bolker, & Walker, 2015). The fixed effects consisted of the *prime structure* * *prime language* * *target language* * *relatedness* * *PP02 version* interaction, and for the random part of the model, we strived for maximal random effects structure as suggested by Barr, Levy, Scheepers, and Tily (2013). However, given the interaction of four within-subject variables (*prime structure* * *prime language* * *target language* * *relatedness*), these models were almost unidentifiable and eventually *relatedness* was discarded as random slope, because forward modeling showed that this slope did not differ significantly across subjects. Hence, the random effects structure consisted of a random intercept for *subject* and a random slope for the *prime structure* * *prime language* * *target language* interaction over subjects.

Transitives. The fixed effects of the transitive model explained 34% of the variance (marginal R^2; Nakagawa & Schielzeth, 2012) and conditional on the random effects, they explained 75% of the variance (conditional R^2; Nakagawa & Schielzeth, 2012). An overview of the model output can be found in Appendix S4 (in the Supporting Information online). There was a significant *prime structure* * *prime language* * *target language* * *relatedness* interaction ($\chi^2(1) = 5.98$, $p = .01$), but this did not differ across PP02 versions ($\chi^2(2) = 3.20$, $p = .20$), showing that case marking and word order did not affect the magnitude of priming. In order to investigate the presence of the priming effect (active-passive) separately for each condition in each PP02 version, we performed planned pairwise contrasts using the phia package. Bonferroni correction for the p-values was applied to account for multiple comparisons.

When the target language was PP02, there was a significant priming effect in all PP02 versions for the related PP02-PP02 condition (baseline: $\chi^2(1) = 36.59$, $p < .001$; case marking: $\chi^2(1) = 47.50$, $p < .001$; SOV: $\chi^2(1) = 53.61$, $p < .001$), the related Dutch-PP02 condition (baseline: $\chi^2(1) = 15.44$, $p = .002$; case marking: $\chi^2(1) = 25.21$, $p < .001$; SOV: $\chi^2(1) = 11.88$, $p = .01$), and for the unrelated PP02-PP02 condition (case marking: $\chi^2(1) = 12.74$, $p = .009$; SOV: $\chi^2(1) = 13.12$, $p = .007$), except for the baseline version ($\chi^2(1) = 7.28$, $p = .17$). For the unrelated Dutch-PP02 condition, there was only a marginally significant priming effect in the case marking version ($\chi^2(1) = 8.78$, $p = .07$).

For the Dutch targets, there was significant priming in all conditions, i.e. related Dutch-Dutch (baseline: $\chi^2(1) = 64.00$, $p < .001$; case marking: $\chi^2(1) = 94.47$, $p < .001$; SOV: $\chi^2(1) = 49.98$, $p < .001$), unrelated Dutch-Dutch (baseline: $\chi^2(1) = 22.91$, $p < .001$; case marking: $\chi^2(1) = 29.42$, $p < .001$; SOV: $\chi^2(1) = 16.91$, $p < .001$), related PP02-Dutch (baseline: $\chi^2(1) = 53.54$, $p < .001$; case marking: $\chi^2(1) = 43.60$, $p < .001$; SOV: $\chi^2(1) = 45.91$, $p < .001$), and unrelated PP02-Dutch (baseline: $\chi^2(1) = 12.57$, $p = .009$; SOV: $\chi^2(1) = 13.13$, $p = .007$), except for the unrelated PP02-Dutch condition in the case marking version ($\chi^2(1) = 7.09$, $p = .19$).

In each PP02 version group, there was a lexical boost effect (i.e. related – unrelated within language) in both PP02 (baseline: $\chi^2(1) = 19.08$, $p < .001$; case marking: $\chi^2(1) = 11.19$, $p = .01$; SOV: $\chi^2(1) = 27.73$, $p < .001$) and Dutch (baseline: $\chi^2(1) = 29.79$, $p < .001$; case marking: $\chi^2(1) = 39.89$, $p < .001$; SOV: $\chi^2(1) = 30.12$, $p < .001$), and a translation equivalent boost (i.e. related – unrelated between languages) from PP02 to Dutch (baseline: $\chi^2(1) = 18.11$, $p < .001$; case marking: $\chi^2(1) = 15.61$, $p < .001$; SOV: $\chi^2(1) = 17.38$, $p < .001$), but not from Dutch to PP02 (baseline: $\chi^2(1) = 5.99$, $p = .17$; case marking: $\chi^2(1) = 4.60$, $p = .38$), except for the SOV version, where there was a marginally significant effect ($\chi^2(1) = 7.25$, $p = .09$). Moreover, priming was stronger within than between languages in the related conditions (Dutch target: $\chi^2(1) = 23.64$, $p < .001$; PP02 target: $\chi^2(1) = 12.69$, $p = .001$), but not in the unrelated conditions (Dutch target: $\chi^2(1) = 1.90$, $p = .67$; PP02 target: $\chi^2(1) = 2.36$, $p = .50$). Overall, priming was larger when Dutch was the target language ($\chi^2(1) = 4.00$, $p = .045$).

To test for the role of proficiency in priming, a new transitive model was fitted in which *PP02 version* was replaced by *accuracy*. There was an effect of accuracy on priming in general (based on the slope of *accuracy* over the active-passive contrast: $\chi^2(1) = 8.27$, $p = .004$) in the sense that priming effects became larger with increasing *accuracy*, but this did not differ significantly across the priming conditions (no significant *prime structure* * *prime language* * *target language* * *relatedness* * *accuracy* interaction: $\chi^2(1) = 0.13$, $p = .72$).

Ditransitives. The marginal R^2 of the model was 30% and the conditional R^2 was 78% (see Appendix S5 in the Supporting Information online, for the model output). There was a significant *prime structure* * *prime language* * *target language* * *relatedness* interaction ($\chi^2(2) = 27.67$, $p < .001$), which did not differ significantly between the PP02 versions ($\chi^2(2) = 0.58$, $p = .75$). Thus, also here, differences in case marking and word order did not affect priming.

Planned pairwise contrasts revealed that for PP02 targets there was a significant priming effect in each PP02 version for the related PP02-PP02 condition (baseline: $\chi^2(1) = 87.11$, $p < .001$; case marking: $\chi^2(1) = 31.17$, $p < .001$; SOV: $\chi^2(1) = 35.33$, $p < .001$) and the unrelated PP02-PP02 condition (baseline: $\chi^2(1) = 30.60$, $p < .001$; case marking: $\chi^2(1) = 9.94$, $p = .04$), except for the SOV version ($\chi^2(1) = 1.52$, $p = 1$). There was no priming from Dutch to PP02 in any of the versions and conditions.

When Dutch was the target, priming was significant in all PP02 versions for related Dutch-Dutch (baseline: $\chi^2(1) = 54.68$, $p < .001$; case marking: $\chi^2(1) = 37.95$, $p < .001$; SOV: $\chi^2(1) = 57.46$, $p < .001$) and unrelated Dutch-Dutch (baseline: $\chi^2(1) = 13.37$, $p = .006$; case marking: $\chi^2(1) = 20.98$, $p < .001$; SOV: $\chi^2(1) = 25.72$, $p < .001$). No significant priming was found from PP02 to Dutch.

There was a lexical boost effect in Dutch (baseline: $\chi^2(1) = 32.30$, $p < .001$; case marking: $\chi^2(1) = 12.18$, $p = .006$; SOV: $\chi^2(1) = 11.77$, $p = .007$) and PP02 (baseline: $\chi^2(1) =$

18.41, $p < .001$; SOV: $\chi^2(1) = 18.29$, $p < .001$), except in the case marking version ($\chi^2(1) = 6.31$, $p = .14$). No translation equivalent boost was found in any of the versions. Furthermore, priming was larger when the target language was Dutch compared to PP02 ($\chi^2(1) = 15.68$, $p < .001$).

Also here, a new model was fitted to test for the effect of accuracy on priming. In this analysis, however, the random effects structure had to be simplified due to convergence issues by discarding *prime language* as random slope (because forward modelling showed that this had the weakest effect). Similar to what was found for the transitives, priming effects were larger for subjects with higher accuracy scores ($\chi^2(1) = 4.21$, $p = .04$), but there was no significant difference between the priming conditions (no significant *prime structure* * *prime language* * *target language* * *relatedness* * *accuracy* interaction: $\chi^2(1) = 0.78$, $p = .38$).

Discussion

In this experiment, we aimed to isolate the effect of case marking and word order in priming between an artificial language and Dutch by comparing priming patterns in three different artificial language versions. For the transitives there was evidence for priming both within and between languages in all PP02 versions, but for the ditransitives there was only priming within languages. There was no significant difference between any of the language versions in the priming patterns for both transitives and ditransitives. In addition, there was a lexical boost effect in Dutch and PP02, whereas the translation equivalent boost was only present in the transitives and only from PP02 to Dutch. This is not surprising, given that the cross-linguistic priming effects were smaller overall compared to priming effects within languages, especially for PP02 targets. As such, the differences are smaller and harder to detect. In addition, priming effects were larger in high-accurate participants compared to low-accurate ones, which is in line with the findings of other studies assessing the relation between language proficiency and cross-linguistic priming (Bernolet et al., 2013; Hwang et al., 2018; Schoonbaert et al., 2007). Furthermore, the overall accuracy was similar in the baseline and SOV condition, but significantly lower in the case marking condition. However, this difference did not lead to differences in the priming effect. People who had experience with case marking languages performed better on the case marking version than people who had no such experience in terms of accuracy, whereas case marking experience did not predict accuracy scores in the other PP02 versions. Although care must be taken in the interpretation of this finding (given the unequal numbers of participants who did or did not have experience with case), one possibility is that knowing a second language with case marking (e.g., German) might be beneficial for learning a further case-marking language (e.g., Russian), because the learners are used to express functional roles in the sentence by means of case markers. This hypothesis deserves some further investigation.

The finding that there was cross-linguistic priming in all PP02 versions for the transitives, implies that differences regarding the presence of case marking or differences in word order do not impede the sharing of transitive structures across languages. Moreover, there was even no difference at all in the priming pattern between the different PP02 versions, suggesting that the sharing occurs to the same extent, regardless of differences in terms of case marking or word order. For the ditransitives, however, there was no evidence for priming between languages in any version, but within-language priming was similar for all versions. Hence, also here, case marking nor word order seems to affect the magnitude of the priming effects. The absence of priming across languages for ditransitives is consistent with the results of the first day in Muylle, Bernolet, et al.'s (submitted) study, where cross-linguistic priming for ditransitives only emerged from the third day on. Given that the result pattern is very similar in both studies after one day of exposure, there are reasons to presume that also in the current study ditransitive cross-linguistic priming will emerge after a longer period of exposure. This suggests that, if ditransitive structures are shared across languages, they require more time to be shared than transitives, possibly because they are more difficult to learn (i.e., there are more phrasal constituents to process). Another possible explanation might be provided by differences in information structure between the alternative formulations (see below). The different results for transitives and ditransitives indicate that the sharing of syntax across languages occurs independently for these structures. In other words, the sharing of transitive structures does not necessarily mean that ditransitive structures are also shared.

Taken together, these findings support the developmental account of shared syntactic representations in late L2-learners (Hartsuiker & Bernolet, 2017), which postulates that within-language syntactic representations develop before (the more abstract) cross-linguistic ones. The strongest priming effects were found for related within-language priming, which is the first type of priming to emerge according to the model, whereas the weakest priming was found for unrelated cross-linguistic priming, the most abstract type of priming and thus the last one to emerge.

The presence of cross-linguistic priming between the case marking version of PP02 and Dutch is in line with findings from studies investigating priming between natural languages with and without case marking (Fleischer et al., 2012; Flett et al., 2012; Hartsuiker et al., 2016; Loebell & Bock, 2003; Salamoura & Williams, 2007). Hence, bilinguals seem to be able to make abstractions of syntactic structures across their languages, despite differences in the morphology or structure of phrasal constituents.

What about differences in word order? The data in the current experiment demonstrate priming between an SVO language (Dutch) and a SOV language (PP02), and thus, support the idea that the order in which constituents appear does not have to be the same in order to establish shared syntax. This finding is in contrast with a series of studies that did not find cross-linguistic priming when the word order differed between languages (Bernolet et al., 2007; Jacob et al., 2017; Loebell & Bock, 2003). Bernolet et al. (2007) concluded from their findings that the same word order was a necessary condition for sharing syntax between languages. However, in a later study (Bernolet et al., 2009), they did find priming between sentences that have a different word order in Dutch and English and this was also the case in some other studies with a variety of language pairs (Chen et al., 2013; Hwang et al., 2018; Shin & Christianson, 2009; Song & Do, 2018; Weber & Indefrey, 2009).

Based on these contradictory findings, Van Gompel and Arai (2018) suggested that priming between languages might be weaker when they differ in word order. But an alternative explanation assumes that priming does not only occur on the level of phrasal constituents, but also on the level of information structure. When both information structure and phrasal structure are the same in prime and target, there will be stronger priming, compared to when there is a match in information structure alone (Bernolet et al., 2009). Hence, in this view, there is priming between SVO and SOV languages because the information structure is the same (e.g., in actives the agent comes before the patient, and in passives the patient comes before the agent, irrespective of the specific position of the verb).

Furthermore, this can also explain why in the current study cross-linguistic priming was found for transitives, but not for ditransitives. Active and passive sentences clearly differ in information structure, because the head of the sentence, which tends to be strongly emphasized, differs between both formulations. In DOs and POs, however, the head of the sentence remains the same, whereas the direct and indirect object, which are usually less emphasized, switch position. Moreover, DOs and POs are closer together in terms of meaning than actives and passives (but see Ziegler & Snedeker, 2018, for an alternative view). As a result, there is only weak information structure priming in ditransitives, and priming occurs mainly on the phrasal level. In contrast, for transitives there is also strong information structure priming.

However, based on this reasoning, one would expect to have differences between the different PP02 versions for both structures because they differ in similarity of phrasal constituents, but this is not the case. Still, it is possible that information structure is primed in early phases of acquisition, whereas the sharing of syntax occurs only later in learning, resulting in similar SVO-SVO and SVO-SOV priming. Our findings show that, when one controls for all other factors that might play a role in the sharing of syntactic representations across languages, priming is equally strong between Dutch and an SVO language as between Dutch and an SOV language. However, the priming between Dutch and the SOV language might be boosted because of the existence of SOV structure in Dutch subordinate clauses. To rule out this explanation, the current findings should be replicated with native speakers of English (a language that does not allow SOV word order). In any case, the artificial language paradigm has a clear advantage compared to natural language studies, which may be confounded by undesired variation or overlap between the languages, for instance in vocabulary.

A remarkable difference between the different PP02 versions, though, is the absence of a PO-dative bias in the SOV PP02 targets (only 35% of the ditransitive responses), whereas this bias tends to be very strong in Dutch (over 77% of the ditransitive responses in the current experiment were PO datives) and also transfers to the other PP02 versions (over 70% of the ditransitive responses were PO datives). One possible explanation for this might be that speakers of Dutch prefer to have the direct object close to the verb (because the direct object is directly affected by the verb), just as in the preferred PO structure ("the clown <u>gives the ball</u> to the cook"), whereas this is not the case for the less preferred DO structure ("the clown <u>gives</u> the cook <u>the ball</u>"). In contrast, in the SOV version of PP02 the direct object is close to the verb in the DO structure ("the clown the cook <u>the ball gives</u>"), but not in the PO structure ("the clown <u>the ball</u> to the cook <u>gives</u>"). Another explanation might be that in Dutch subordinate clauses, which have SOV structure, there are three instead of two alternative dative formulations: a) a DO, for instance, "… dat de clown de kok de bal geeft" [*that the clown the cook the ball gives], b) a pre-verb PO, for instance, "… dat de clown de bal aan de kok geeft" [*that the clown the ball to the cook gives], and c) a post-verb PO, for instance, "… dat de clown de bal geeft aan de kok" [*that the clown the ball gives to the cook]. In other words, the structure that is typically preferred in Dutch, is spread out over two different formulations. As such, the relative frequency of each of these formulations is lower compared to the DO alternative. In any case, this finding suggests that a different word order might prevent the transfer of structural preferences from the native language to another language without affecting the preference in the L1.

The fact that the current findings seem to replicate the findings of another study using the same paradigm (Muylle, Bernolet, et al., submitted), indicates that the artificial language learning paradigm might yield reliable and robust priming effects. In addition, the findings are in line with those of other studies using natural languages (cf. supra). Nevertheless, one should not forget that the use of artificial languages inevitably leads to situations that differ from real-life language learning situations in terms of, amongst others, the motivation to master the language. Moreover, the number of PP02 nouns and verbs is very limited, which makes generalization faster and easier during artificial language learning than in real-life language learning.

A major limitation of this study is that there are no data on how the priming effects would evolve in later sessions, especially for the ditransitives. The current study does not provide evidence for cross-linguistic priming of ditransitive structures after one session and it is uncertain whether this would emerge in a later session. Still, the fact that the priming pattern in the current study is very similar to that of the first day in Muylle, Bernolet, et al.'s (submitted) study indicates that it is reasonable to expect that a similar evolution would take place. Of course, a multiple session study would be necessary to test this hypothesis.

Conclusions

In sum, the current study shows similar priming between Dutch and an artificial language that either had the same word order and morphosyntactic structure, had a different morphosyntactic structure (i.e., overt case marking), or a different word order. These results suggest that late bilinguals are able to abstract syntactic representations over languages to the extent that word order or occasional case marking does not hinder cross-linguistic priming. Further studies are needed to elucidate whether these findings can be replicated with L1s that are different from Dutch, for instance languages that have a more fixed word order or a case marking system that is typologically different from the one in our artificial language.

Notes

[1] Apart from some exceptions, such as pronouns (e.g., “she” vs. “her”).

[2] Participants who were able to guess the goal of the experiment, based on their answer on the question about the goal.

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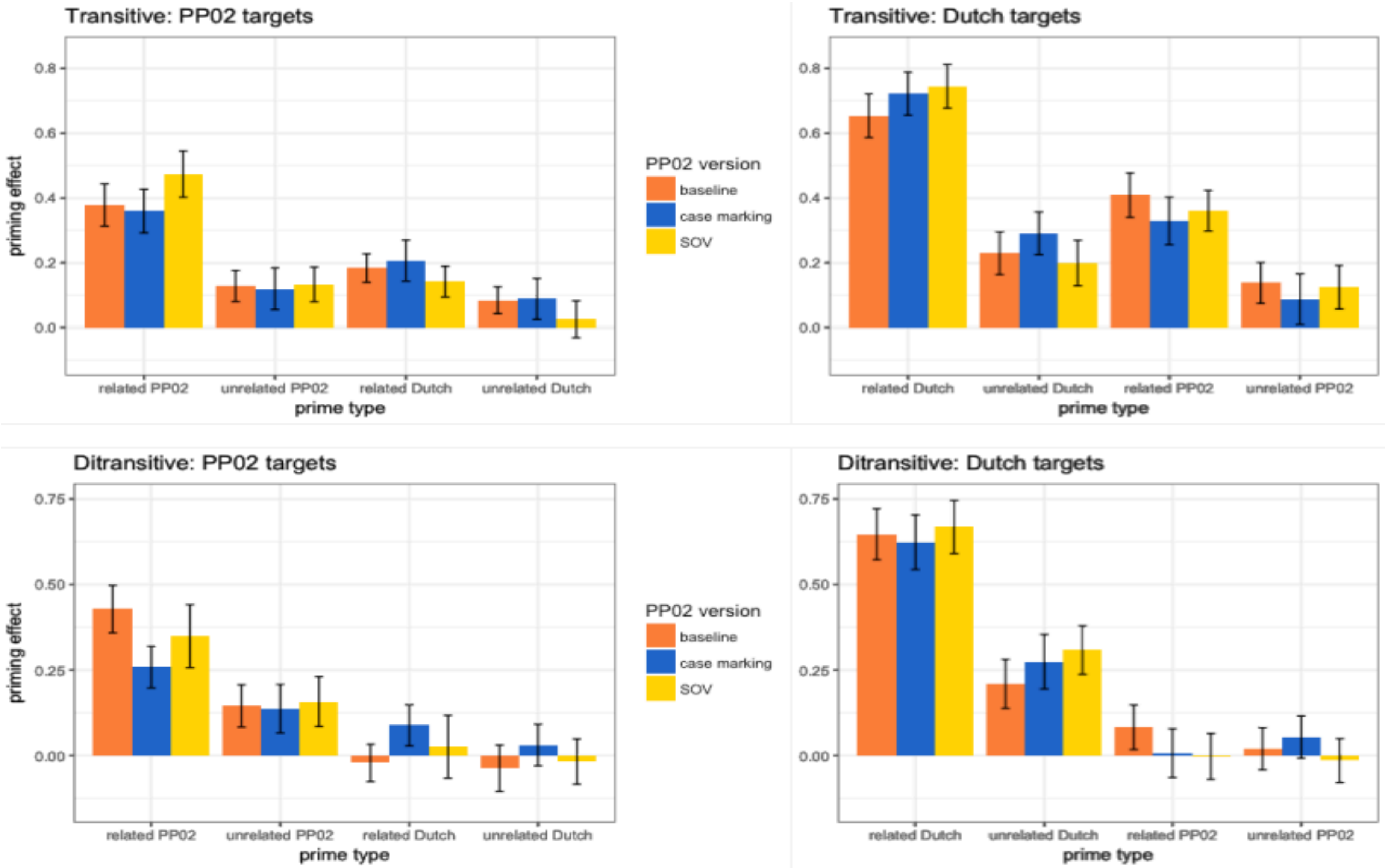

Figure 1. *Priming effects split up per condition for each PP02 version.*

Appendix S1. *List of PP02 vocabulary and their English translation.*

	PP02	Translation
nouns	*berwa*	waitress
	dettus	clown
	fuipam	cook
	hapolkt	pirate
	junte	policeman
	limpolp	swimmer
	rupties	sailor
	sifuul	hat
	tusko	teacher
	tuulmas	ball
	wapi	monk
	zafol	knight
verbs	*jalt*	to wave
	sjac	to run
	firp	to shoot
	sorf	to tickle
	zwif	to kiss
	dwok	to sell
	heuf	to give
	stie	to show

Appendix S2. *Examples of the application of the coding scheme*.

Movie clip	Response	Coding
clownKissCook	Fuipam zwifsi dettus *Cook kisses clown*	active
clownKissCook	Dettus nast zwifo ka fuipam *Clown is kissed by cook*	passive
clownGiveCookHat	Dettus heufsi sifuul fuipam *Clown gives hat cook*	DO
clownGiveCookHat	Dettus heufsi fuipam bo sifuul *Clown gives cook to hat*	PO

Appendix S3. *Number of responses for each structure.*

A) Transitive

PP02 version	Target	Priming condition	Response		
			Active	Passive	Other
Baseline	PP02	Related PP02	301	78	3
		Unrelated PP02	335	42	3
		Related Dutch	332	43	4
		Unrelated Dutch	351	28	3
	Dutch	Related Dutch	248	126	10
		Unrelated Dutch	290	71	22
		Related PP02	275	90	16
		Unrelated PP02	304	58	19
Case marking	PP02	Related PP02	263	112	9
		Unrelated PP02	312	67	5
		Related Dutch	299	80	5
		Unrelated Dutch	315	64	5
	Dutch	Related Dutch	227	143	14
		Unrelated Dutch	255	92	37
		Related PP02	266	90	28
		Unrelated PP02	291	62	31
SOV	PP02	Related PP02	285	97	2
		Unrelated PP02	329	53	2
		Related Dutch	322	61	1
		Unrelated Dutch	330	53	1
	Dutch	Related Dutch	224	138	22
		Unrelated Dutch	266	76	42
		Related PP02	278	78	28
		Unrelated PP02	287	64	33

B) Ditransitive

PP02 version	Target	Priming condition	Response		
			PO	DO	Other
Baseline	PP02	Related PP02	237	141	5
		Unrelated PP02	276	103	1
		Related Dutch	269	107	4
		Unrelated Dutch	275	100	5
	Dutch	Related Dutch	243	128	11
		Unrelated Dutch	286	73	23
		Related PP02	298	68	17
		Unrelated PP02	288	68	27
Case marking	PP02	Related PP02	258	118	8

		Unrelated PP02	258	115	11
		Related Dutch	277	93	14
		Unrelated Dutch	271	96	17
	Dutch	Related Dutch	248	116	20
		Unrelated Dutch	297	58	29
		Related PP02	295	65	24
		Unrelated PP02	301	62	21
SOV	PP02	Related PP02	135	238	11
		Unrelated PP02	128	244	12
		Related Dutch	124	245	15
		Unrelated Dutch	133	237	14
	Dutch	Related Dutch	235	132	17
		Unrelated Dutch	290	68	25
		Related PP02	295	64	25
		Unrelated PP02	288	71	25

Appendix S4. *Transitive model output.*

Summary of the fixed effects in the multilevel logit model (*N* = 8850; log-likelihood= -2768.8)				
Fixed effect	*β*	*SE*	Wald's *Z*	p-value
(Intercept)	6.07	(0.887)	6.85	<0.001
Prime Structure	-7.06	(0.883)	-8.00	<0.001
Prime Language	-1.51	(0.960)	-1.58	0.115
Target Language	0.23	(1.203)	0.19	0.847
Relatedness	-2.53	(0.817)	-3.10	0.002
Case Marking	-1.06	(1.019)	-1.04	0.300
SOV	0.51	(1.363)	0.37	0.710
Prime Structure * Prime Language	2.87	(0.996)	2.88	0.004
Prime Structure * Target Language	3.70	(1.201)	3.08	0.002
Prime Language * Target Language	1.77	(1.438)	1.23	0.219
Prime Structure * Relatedness	4.73	(0.867)	5.46	<0.001
Prime Language * Relatedness	1.57	(0.944)	1.66	0.097
Target Language * Relatedness	2.04	(1.074)	1.90	0.057
Prime Structure * Case Marking	0.46	(1.018)	0.45	0.651
Prime Structure * SOV	-0.99	(1.362)	-0.73	0.467
Prime Language * Case Marking	0.11	(1.048)	0.10	0.920
Prime Language * SOV	-0.14	(1.415)	-0.10	0.918
Target Language * Case Marking	-0.96	(1.282)	-0.75	0.453
Target Language * SOV	-2.39	(1.562)	-1.53	0.126
Relatedness * Case Marking	0.43	(1.003)	0.43	0.667
Relatedness * SOV	-1.07	(1.349)	-0.80	0.427
Prime Structure * Prime Language * Target Language	-5.12	(1.517)	-3.37	0.001
Prime Structure * Prime Language * Relatedness	-2.32	(1.026)	-2.26	0.024
Prime Structure * Target Language * Relatedness	-2.66	(1.204)	-2.21	0.027
Prime Language * Target Language * Relatedness	-2.43	(1.368)	-1.77	0.076
Prime Structure * Prime Language * Case Marking	0.57	(1.117)	0.51	0.610
Prime Structure * Prime Language * SOV	0.88	(1.467)	0.60	0.548
Prime Structure * Target Language * Case Marking	0.17	(1.268)	0.14	0.892
Prime Structure * Target Language * SOV	2.34	(1.551)	1.51	0.131
Prime Language * Target Language * Case Marking	-0.61	(1.417)	-0.43	0.669
Prime Language * Target Language * SOV	2.17	(1.772)	1.23	0.220
Prime Structure * Relatedness * Case Marking	-0.52	(1.080)	-0.48	0.631
Prime Structure * Relatedness * SOV	1.43	(1.410)	1.02	0.310
Prime Language * Relatedness * Case Marking	-0.10	(1.174)	-0.09	0.930
Prime Language * Relatedness * SOV	0.51	(1.518)	0.34	0.736
Target Language * Relatedness * Case Marking	-0.25	(1.297)	-0.20	0.845
Target Language * Relatedness * SOV	0.98	(1.576)	0.62	0.535

Prime Structure * Prime Language * Target Language * Relatedness	3.76	(1.537)	2.45	0.014
Prime Structure * Prime Language * Target Language * Case Marking	0.56	(1.550)	0.36	0.719
Prime Structure * Prime Language * Target Language * SOV	-3.12	(1.883)	-1.66	0.098
Prime Structure * Prime Language * Relatedness * Case Marking	0.06	(1.299)	0.04	0.965
Prime Structure * Prime Language * Relatedness * SOV	-1.36	(1.617)	-0.84	0.400
Prime Structure * Target Language * Relatedness * Case Marking	-0.39	(1.464)	-0.27	0.788
Prime Structure * Target Language * Relatedness * SOV	-2.06	(1.726)	-1.19	0.234
Prime Language * Target Language * Relatedness * Case Marking	1.33	(1.655)	0.81	0.420
Prime Language * Target Language * Relatedness * SOV	-1.05	(1.991)	-0.53	0.597
Prime Structure * Prime Language * Target Language * Relatedness * Case Marking	-0.85	(1.882)	-0.45	0.651
Prime Structure * Prime Language * Target Language * Relatedness * SOV	2.58	(2.191)	1.18	0.238

Appendix S5. *Ditransitive model output.*

Summary of the fixed effects in the multilevel logit model (N = 8812; log-likelihood= -3136.5)				
Fixed effect	β	*SE*	Wald's Z	p-value
(Intercept)	5.27	(0.829)	6.36	<0.001
Prime Structure	-6.22	(0.841)	-7.40	<0.001
Prime Language	-2.65	(0.855)	-3.10	0.002
Target Language	-2.70	(1.070)	-2.53	0.012
Relatedness	-2.08	(0.665)	-3.13	0.002
Case Marking	1.09	(1.255)	0.87	0.386
SOV	-0.08	(0.937)	-0.09	0.930
Prime Structure * Prime Language	5.36	(0.903)	5.94	<0.001
Prime Structure * Target Language	5.40	(0.934)	5.78	<0.001
Prime Language * Target Language	3.90	(1.013)	3.85	<0.001
Prime Structure * Relatedness	4.08	(0.718)	5.68	<0.001
Prime Language * Relatedness	1.87	(0.744)	2.51	0.012
Target Language * Relatedness	2.16	(0.753)	2.86	0.004
Prime Structure * Case Marking	-0.92	(1.271)	-0.72	0.471
Prime Structure * SOV	-0.05	(0.958)	-0.05	0.962
Prime Language * Case Marking	-1.28	(1.274)	-1.00	0.316
Prime Language * SOV	-0.11	(0.959)	-0.12	0.905
Target Language * Case Marking	-0.70	(1.572)	-0.45	0.655
Target Language * SOV	-5.10	(1.385)	-3.68	<0.001
Relatedness * Case Marking	0.12	(1.286)	0.09	0.928
Relatedness * SOV	1.34	(0.985)	1.36	0.173
Prime Structure * Prime Language * Target Language	-9.12	(1.103)	-8.27	<0.001
Prime Structure * Prime Language * Relatedness	-3.72	(0.846)	-4.40	<0.001
Prime Structure * Target Language * Relatedness	-3.98	(0.862)	-4.62	<0.001
Prime Language * Target Language * Relatedness	-2.50	(0.916)	-2.73	0.006
Prime Structure * Prime Language * Case Marking	1.63	(1.342)	1.21	0.225
Prime Structure * Prime Language * SOV	0.76	(1.046)	0.73	0.466
Prime Structure * Target Language * Case Marking	0.74	(1.387)	0.53	0.596
Prime Structure * Target Language * SOV	1.62	(1.179)	1.38	0.168
Prime Language * Target Language * Case Marking	-0.02	(1.448)	-0.01	0.991
Prime Language * Target Language * SOV	1.63	(1.252)	1.31	0.192
Prime Structure * Relatedness * Case Marking	-0.12	(1.341)	-0.09	0.928
Prime Structure * Relatedness * SOV	-1.40	(1.053)	-1.33	0.185
Prime Language * Relatedness * Case Marking	0.43	(1.374)	0.31	0.756
Prime Language * Relatedness * SOV	-1.36	(1.088)	-1.25	0.210
Target Language * Relatedness * Case Marking	-0.75	(1.395)	-0.54	0.592
Target Language * Relatedness * SOV	-1.32	(1.109)	-1.19	0.235

Prime Structure * Prime Language * Target Language * Relatedness	5.71	(1.085)	5.26	<0.001
Prime Structure * Prime Language * Target Language * Case Marking	0.60	(1.576)	0.38	0.705
Prime Structure * Prime Language * Target Language * SOV	-0.39	(1.417)	-0.28	0.782
Prime Structure * Prime Language * Relatedness * Case Marking	-0.64	(1.493)	-0.43	0.669
Prime Structure * Prime Language * Relatedness * SOV	1.13	(1.229)	0.92	0.357
Prime Structure * Target Language * Relatedness * Case Marking	0.74	(1.526)	0.49	0.627
Prime Structure * Target Language * Relatedness * SOV	1.43	(1.263)	1.13	0.258
Prime Language * Target Language * Relatedness * Case Marking	0.02	(1.580)	0.01	0.992
Prime Language * Target Language * Relatedness * SOV	0.51	(1.318)	0.39	0.696
Prime Structure * Prime Language * Target Language * Relatedness * Case Marking	-0.87	(1.795)	-0.48	0.629
Prime Structure * Prime Language * Target Language * Relatedness * SOV	-1.16	(1.567)	-0.74	0.461