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Priming of Possessive Constructions in German: A Matter of Preference Effects?

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Abstract: We investigated structural priming in adult native speakers, focusing on possessive constructions in German, where the two alternative structures involved differ in frequency. According to error-based learning approaches to priming, the less frequent structure should lead to a larger prediction error and larger priming effects than the more frequent structure. In a comparison of preferences during a pretest and preferences during priming, we did not find evidence of such an inverse preference effect. Moreover, during priming, we observed increasing production rates of the preferred structure, hence, a cumulative priming effect. In line with hybrid models of priming, we propose that two mechanisms, namely, a mechanism learning from input as well as a mechanism accumulating activation during comprehension and production, are involved in the temporal development of priming effects. Moreover, we suggest that the interaction of the two mechanisms may depend on prior experience with the alternative structures.

Keywords: cumulative structural priming; error-based learning; (inverse) preference effect; possessive constructions

Citation: Schimke, Sarah, and Sandra Pappert. 2024. Priming of Possessive Constructions in German: A Matter of Preference Effects? *Languages* 9: 170. https://doi.org/10.3390/languages9050170

Academic Editors: Naomi Havron and Chiara Gambi

Received: 21 August 2023
Revised: 10 April 2024
Accepted: 21 April 2024
Published: 8 May 2024

1. Introduction

Structural priming refers to the tendency of speakers to reuse previously heard or read constructions (Bock 1986). An error-based implicit learning mechanism has been proposed to explain the phenomenon (Chang et al. 2000). The idea that structural priming is an instance of learning comes with specific claims about the sensitivity of the learning mechanism to the given input and produced output, about the representations that are involved in learning, and about the changes that apply to these representations over time (for an overview, see, e.g., Jaeger and Snider 2013; Pickering and Ferreira 2008). The current study takes up these issues and investigates priming effects for possessive constructions in adult speakers of German.

The dual-path error-based learning model (henceforth, error-based learning model) assumes the parallel processing of thematic relations and of linear order, the latter relying on transition probabilities (Chang 2002; Chang et al. 2006, 2012). During syntactic processing of the input, speakers continuously update their knowledge about the likelihood of a sequence in a given context. In line with other predictive coding accounts (following Rao and Ballard 1999; Friston 2018), it is assumed that language users will predict what syntactic unit they are most likely to encounter next, at least in the case that the situation is sufficiently constrained to allow for such predictions (for an overview, see Huettig 2015). If the subsequent input deviates from a current prediction, language users will experience a prediction error, and this will lead to an updating of their internal model of the likelihood of a specific sequence. This mechanism constitutes the fundament of learning. Based on the new internal model, speakers will generate updated predictions for the subsequent input, and will themselves be relatively more likely to produce the structure they had not predicted to occur previously. Importantly, this process is assumed to be sensitive to the

size of the prediction error, i.e., the probability difference between the predicted and the encountered input: larger prediction errors are assumed to lead to larger adaptions of the internal model. In the context of structural priming, this assumption has been claimed to be mirrored in larger priming effects for relatively rare, and hence unexpected, structures compared to alternative, more frequent structures that express the same meaning. There is evidence of such inverse preference effects (e.g., Hartsuiker and Kolk 1998; Scheepers 2003; Jaeger and Snider 2013), but they appear under a variety of conditions, and it is not always clear whether it is necessary to assume a learning mechanism to explain the effect.

This paper is structured as follows: we will first summarize what is known about inverse preference effects during structural priming and about the temporal development of priming effects. We will present explanations as to why such patterns are observed under some conditions but not all. We will then introduce the structures under investigation in the current study, our research questions, and data from a structural priming experiment. Our data provide evidence of preference, rather than inverse preference, effects. In the discussion, we will propose potential explanations for the pattern, point to limitations of our study, and outline avenues for future research.

2. Background: Factors in the Development of Structural Priming Effects

In studies on structural priming during language production, the effects of primes on the use of structural alternations are measured. The relative proportion of two alternative expressions is expected to vary as a function of the prime structure (e.g., Bock 1986). For example, priming of the dative alternation is attested for PO (prepositional object) and DO (double object) primes and responses, if the relative proportion of PO responses (PO/(PO + DO)) increases after the presentation of PO primes as compared to DO primes. There are at least two prominent accounts of structural priming that differ in the mechanisms assumed to underly these effects, a residual activation account and the implicit learning account that was briefly mentioned above. The residual activation account (Pickering and Branigan 1998) posits a lexical network, with nodes for lemmas and for the syntactic contexts they appear in. According to this model, the production of a word in a context leads to an increase in the activation of the corresponding lexical and structural nodes. This pre-activation leads to the easier activation of these nodes during subsequent encoding, giving rise to priming effects. The original proposal focuses on verb lemmas, but it was also adapted to noun lemmas (Cleland and Pickering 2003; Bernolet et al. 2013). The implicit learning account holds that priming is an instance of learning, in that a heard or read prime affects the speaker's internal representation of the probability of the corresponding construction or sequence of words (Chang et al. 2000). Priming effects are modeled as resulting from a mismatch of the predicted and the encountered input, i.e., a prediction error (Chang et al. 2006).

Over the last decades, the strength of structural priming has been found to be modulated by several factors that are potentially informative about the underlying mechanisms. These factors relate to the linguistic similarities between primes and responses, to biases towards one of the alternative structures, and to the temporal development, as well as the longevity, of the priming effects.

Priming arises when primes and responses share linguistic properties, e.g., phrase structure (Bock 1986). Phrase structural effects are boosted when lexical materials, such as verbs in the case of the dative alternation (Pickering and Branigan 1998) or nouns in the case of possessive constructions (Bernolet et al. 2013), are repeated in primes and responses. According to the residual activation model, the lexical boost is due to the repeated activation of the link between a lexical and structural node (Pickering and Branigan 1998). The error-based learning model needs an additional mechanism, i.e., explicit memory, to deal with these lexically mediated effects, since the dual-path mechanism operates on abstract linguistic categories and produces relatively smaller effects (Chang et al. 2006).

In structural alternations, the use of structural variants may be biased, and one variant may be preferred over the other variant. For example, the PO structure may be produced

more frequently in dative alternation contexts than the DO structure. Such preferences have been found to influence structural priming. The inverse preference effect refers to the finding of relatively stronger priming by less preferred structures than by more preferred structures (cf. Ferreira and Bock 2006; Hartsuiker and Kolk 1998; Scheepers 2003). The repeated use of an otherwise less preferred structure within the experiment changes the relative preference of this structure more dramatically than that of the more preferred structure. For the dative alternation referred to above, this means that a DO prime may exhibit a stronger effect on responses than a PO prime. Whereas such a pattern of results is not easily accounted for by the residual activation model, it may be explained by error-based learning: The model operates with a mechanism that predicts the next word in a structure (e.g., a prime) on the basis of transition probabilities. It learns from a prediction error that occurs whenever the predicted word (class) and the actual word (class) in the input differ. The lower the probability of the actual word is, the larger is the prediction error it evokes and the stronger is the subsequent adaptation of transition probabilities (Chang et al. 2006). Thus, the error-based learning model predicts inverse preference effects, i.e., stronger priming of the less probable word. In addition, several studies found an impact of verb-specific preferences on the strength of priming (Bernolet and Hartsuiker 2010; Jaeger and Snider 2013). This has been accounted for in terms of surprisal (an unexpected word is more informative than an expected one (Hale 2001); cf. Scheepers 2003), which resembles the error-driven model and allows for an integration of verb-specific information, without assuming an additional explicit memory mechanism (cf. Chang and Fitz 2014).

To test for inverse preference effects, preferences during priming have to be compared to preferences without priming. Priming-neutral preference data may be gained from baseline trials within a priming experiment or from a corpus. The comparison of corpus data and experimental production data may be problematic, as constraints on the data may differ. Most corpora are based on written language, whereas many priming experiments elicit spoken language, such that the degree of elaboration, complexity, and the incidence of academic language will differ. Moreover, experimenters may impose constraints on materials that increase the probability of the less preferred structure, as in the case of animacy constraints on the patient in transitive events to increase the proportion of passive responses (Bock 1986). If corpus data do not mirror these constraints, they will not be directly comparable, and it would be better to measure preferences within the experimental situation with materials similar to those presented in the priming trials.

Next, it also has to be taken into account that asymmetrical priming could be related to ceiling or floor effects. The structure that is already prevalent may have reached an upper limit (ceiling) and therefore may not gain anymore by priming. The only structure that can be primed, then, is the less preferred structure (Hartsuiker et al. 1999; Segaert et al. 2016). The assumption of ceiling effects is plausible, but it is far from clear which limit applies and whether it is reached at around 80% (Hartsuiker et al. 1999) or above 90% (Segaert et al. 2016). The counterparts of ceiling effects are floor effects for structures that are rarely produced (see Pickering et al. 2002).

Time is an additional factor in structural priming. Even though intervening trials with a structure different from the primes may reduce priming effects (Bock and Kroch 1989), structural priming has been shown to persist across trials (Bock and Griffin 2000), as well as from a priming phase to a response phase (Kaschak 2007). Effects of structural priming are attested a week (Kaschak et al. 2011) or even a month after the experimental session (Heyselaar and Segaert 2022). By contrast, the lexical boost decays quickly and cannot be traced across trials (Hartsuiker et al. 2008). This longevity of "abstract", as opposed to lexically mediated, structural priming effects favors the implicit learning account, as well as the assumption of a different mechanism behind the lexical boost (Chang et al. 2006).

Finally, cumulative priming effects may arise as the experiment proceeds (Hartsuiker and Kolk 1998; Hartsuiker and Westenberg 2000). Structural priming does not decay completely but persists across trials (Reitter et al. 2011). Subsequent primes (Jaeger and Snider 2013) and responses (Jacobs et al. 2019) add to the overall priming potential, such

that it accumulates over a repeated input or use of the critical structures. The strength of priming thus increases across experimental trials, even though additions are not necessarily linear (cf. Bernolet et al. 2013; Jaeger and Snider 2013). This pattern is predicted by residual activation models. The error-based learning model predicts the even longer persistence of priming effects, but they are suggested to develop slowly (Chang et al. 2006). Moreover, if cumulative effects are to be explained by an error-based mechanism, the less frequent structure should gain relative to the more frequent one. In line with this, Jaeger and Snider (2013) report both the cumulative priming of the less frequent structure and a decrease in verb-specific inverse preference effects across prime trials, the latter being commensurate with a decrease in surprisal by the less frequent structure (Jaeger and Snider 2013). Some approaches have combined error-based learning and activation-based processes, in order to account for temporal developments (Jacobs et al. 2019; Reitter et al. 2011), a suggestion that we will come back to in the Discussion section.

The temporal development of priming effects across experimental trials is theoretically intriguing, but it also has methodological implications: Since preferences are subject to priming, it might be less advisable to measure preferences by presenting baseline primes intermixed with experimental primes than to measure preferences in a phase before the experimental manipulation of primes (for a recent combination of both, a pre-priming baseline phase and baseline primes intermixed with critical primes, see Van Lieburg et al. 2023).

To summarize, "abstract" structural priming effects differ from lexically mediated effects, in that the former are long-lived and the latter are short-lived. Both may be subject to structural preferences. Ceiling and floor effects may hinder the development of priming effects. If not overridden by ceiling or floor effects, error-based models predict that priming effects should be stronger for less expected, e.g., less frequent, structures. Such an inverse preference effect can best be tested by comparing the impact of primes on structural preferences to preferences that have been established independent of priming. In addition, there may be cumulative effects during priming, such that structural preferences change across a priming phase and one structure gains in production rates at the expense of the other structure. If cumulative priming is due to an error-based mechanism, then it should occur in favor of the initially less frequent structure (cf. Jaeger and Snider 2013), even though the size of the error-based effect may decrease after repeated exposure and subsequent changes in syntactic representations. As for the longevity of effects, error-based models predict changes to structural preferences to be small but lasting. Activation models assume that activation may accumulate across trials, but it is not clear how long such effects can persist.

3. The Current Study

The aim of the current study is to provide further evidence on the potential impact of structural preferences on the size, the temporal development, and the persistence of priming effects. We look at constructions that have not been previously looked at, namely, possessive constructions in German (genitive construction vs. prepositional phrase construction, cf. (1) and (2) below). The structural bias associated with these structures is quite strong, which should lead to large prediction errors and thus provides an important test case for error-based models. We do not evoke a lexical boost. The relations expressed are always those between a protagonist and an object possessed by the protagonist (e.g., *the artist's rose*), in a design modeled after studies by Bernolet (2008) on the priming of possessive constructions in English. We measure preferences across priming trials and in tests preceding and following the experiment (pre- and post-tests), such that we can test for:

- An (inverse) preference effect (by comparing pretest preferences to the preferences induced during priming);
- Cumulative priming during the priming phase (by observing whether one structure gains in production rates during the priming phase relative to the alternative structure);

- Persistence of the effects during a post-test in the absence of primes (by comparing production rates between the pretest and post-test).

The alternative structures we focus on are a postnominal genitive construction (1) compared to a postnominal prepositional phrase attribute with *von* (2).

(1) Genitive construction:

Die	*Rose*	*des*	*Künstlers-s*	*ist rot.*
the.NOM	rose	the.GEN	artist-GEN	is red

(2) Prepositional phrase construction:

Die	*Rose*	*von*	*dem*	*Künstler*	*ist rot.*
the.NOM	rose	of	the.DAT	artist	is red

The artist's rose/the rose of the artist is red.

Note that we also conducted a second experiment, in which we compared the postnominal genitive construction to the (archaic) prenominal genitive construction. As there were no occurrences of the prenominal genitive in the pretest or post-test of that experiment, which makes it impossible to compare priming effects to a baseline or to test the persistence of effects, we aborted this experiment after having tested 16 participants. For the sake of completeness, this experiment is reported, and its results are briefly discussed, in Appendix A.

Concerning postnominal genitives and postnominal prepositional phrases with *von* (which we will refer to simply as "*von*-phrases" in the following), a recent large-scale corpus analysis (Kopf 2021) found that both are frequently used to express possessive relations (see also Kopf and Weber 2022; Smith 2003). Which structure is preferred is related to the formal properties of the attributive noun phrase; for noun phrases containing an article, there is a preference for the genitive over the *von*-phrase (e.g., *Die Nutzung der neuen Technologien*, 'the usage the(GEN) new(GEN) technologies', is strongly preferred over *Die Nutzung von den neuen Technologien*, 'the usage of the new technologies'), while for noun phrases without an article, genitives and *von*-phrases are used to an equal degree, approximatively (*Die Nutzung neuer Technologien*, 'The usage new(GEN) technologies', is used to a similar degree to *Die Nutzung von neuen Technologien*, 'the usage of new technologies'—example taken from Kopf and Weber 2022; see also Smith 2003). This pattern has been explained by a tendency of speakers to use genitive-marked noun phrases more often when this results in unambiguous case marking and less often when the case marking would be ambiguous. As the adjectival and noun declension paradigms are characterized by syncretism, speakers are comparatively more hesitant to use genitives for noun phrases that are case marked on nouns and/or adjectives only. For the stimuli of the current study, all noun phrases used by the confederate speaker contained a definite article agreeing with a masculine noun, which unambiguously inflected for case. This means that there were ideal conditions for the use of the genitive. It has to be noted, however, that the available corpus data are written (Kopf 2021; Smith 2003) and that *von*-phrases may be more frequent in informal spoken speech (cf. Bredel and Maaß 2016).

The experiment followed the confederate scripting paradigm (Branigan et al. 2000) that has been shown to produce stronger effects than other priming paradigms (Mahowald et al. 2016). We determined relative frequencies in a pretest, priming, and post-test phase to control for preferences induced by experimental materials and the spoken modality.

It is worth recalling that, as outlined in the introduction, if the prevalence of genitive structures over *von*-phrases can be confirmed in the pretest, error-based learning models would expect the subsequent priming effects to be stronger for the *von*-phrase than for the genitive phrase. This should be reflected in an inverse preference effect (e.g., in the trials where the *von*-phrase is used as a prime during the priming phase, it should cause a larger change in the relative frequency of the *von*-phrase and genitive than when the genitive is used as prime). Moreover, if error-based models are applied to cumulative priming, they would also predict that the relatively less frequent structure should continue to cause a stronger prediction error than the relatively more frequent structure, as long as it remains

the less frequent one overall. While the size of the prediction error could decrease, this should nevertheless lead to an overall increase in the comparatively less frequent structure over time (cf. Jaeger and Snider 2013). Finally, according to error-based models, if an advantage for the initially less frequent structure can be observed, this effect should persist during the post-test phase.

4. Method

4.1. Participants

Forty native speakers of German (23 female, 16 male, 1 non-binary; mean age: 25, range: 19–34) participated in the experiment. All of them were students at TU Dortmund University or at Heidelberg University, and none of them were bilingual as a child.

4.2. Materials

We created two sets of pictures, a description set and a verification set. An item was defined as the combination of a picture from the verification set, together with the description of this picture given by the confederate speaker (for experimental items in the priming phase: the prime), and the description picture meant to elicit the description by the participant (the target). For the pre- and post-test phase, there were 12 experimental items and 24 filler items. For the priming phase, there were 24 experimental items and 48 filler items. Figure 1a,b illustrate a combination of a verification picture and a following description picture from a pretest trial without priming (Figure 1a), and a priming trial of the priming phase (Figure 1b). The participant had to first verify the confederate speaker's description of the verification picture (1) and then turn to the description picture (2) to describe it.

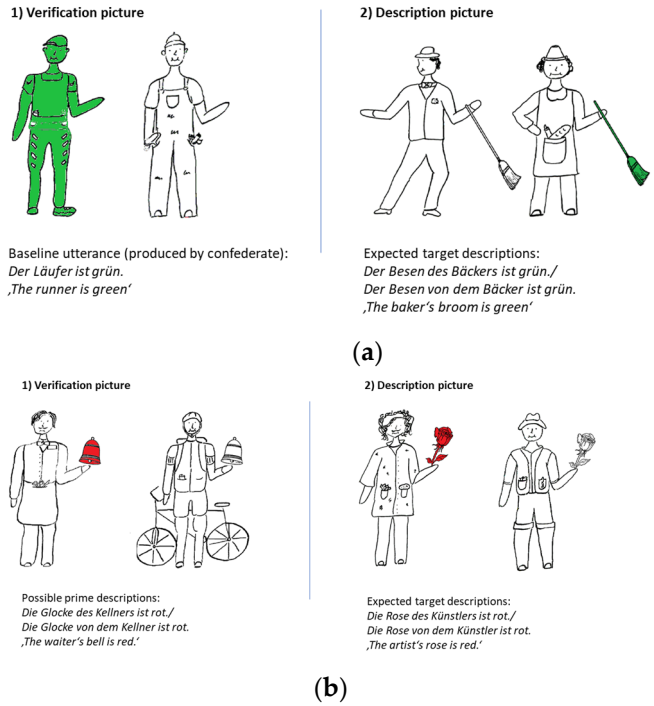

Figure 1. (**a**) Verification and description pictures from a pretest trial. (**b**) Verification and description pictures from a priming trial.

Items were created, closely following the procedure described in Bernolet (2008) (see also Bernolet et al. 2013), except that we used a larger variety and greater number of fillers and a higher number of different characters, to reduce the likelihood of different experimental trials influencing each other. Different items were created for the pre- and post-test phase than for the priming phase.

Concerning the priming phase, for the experimental items, both the verification picture and the description picture consisted of drawings of two characters with an identical object in their hand (identical to the set-up in Bernolet 2008, see Figure 1b). The object held by one of the characters was colored in blue, green, yellow or red, while the rest of the picture was black and white. Pictures were created based on twelve different characters and 48 objects. All characters could be described by masculine, disyllabic nouns in German, which fell in frequency classes 9–12 according to the *Projekt Deutscher Wortschatz* (mean: 10.83; Leipzig Corpora Collection 2011; cf. Goldhahn et al. 2012), and all ended with the suffix *–er* and formed the genitive form by adding the suffix *–s*. The objects were taken from the Snodgrass and Vanderwart (1980) picture database. These descriptions consisted of 48 nouns, 16 of each of the three German gender classes. A total of 26 of the nouns were monosyllabic and 22 were disyllabic. The nouns fell into frequency classes 8–15 according to the *Projekt Deutscher Wortschatz* (mean for the verification set: 11.75, mean for the description set: 11.92). For the description and verification set of each item, the objects of the verification and the description set were matched for gender and number of syllables. Moreover, for each item, the four characters appearing on the elicitation and description picture were always different from each other, and the color of the object was always identical in the two pictures. Each character appeared twice in each of the following positions: on the verification picture holding the colored object, on the verification picture not holding the colored object, on the elicitation picture holding the colored object, and on the elicitation picture not holding the colored object. The character holding the colored object occurred on the left or right side of the screen for half of the pictures, respectively, and each of the four colors appeared equally often on the pictures and in the confederate's descriptions. The position of the color was kept constant, such that all red and blue objects always appeared to the left and all yellow and green objects to the right.

Regarding the filler items of the priming phase, all 48 filler items consisted of pairs of the same characters that were also used for the experimental items but without any objects, as in Bernolet (2008). In half of the cases, only one of the two characters was colored (as in Bernolet 2008, again), while in the other half of the cases, both characters were completely colored, always in the same color. Whether one or both characters were colored was crossed across the verification and the elicitation set, such that all four possible combinations (one character colored in the verification set, one in the elicitation set, one in the verification set, two in the elicitation set, and so on) occurred equally often. All colors appeared equally often on the pictures and in the confederate's descriptions. The position of the colors was kept constant, such that single yellow characters always appeared on the left of the screen, single blue characters on the right, and that in pictures where both characters were colored, these were always either both red or both green.

When describing the verification picture, the confederate used the following three types of structures:

(3) For filler items with one colored character:
Der Kellner ist blau.
'The waiter is blue'.

(4) For filler items with two colored characters:
Der Kellner und der Radler sind blau.
'The waiter and the cyclist are blue.'

(5) For experimental items (genitive or *von*-phrase constructions):
Die Glocke des Kellners ist rot.
Die Glocke von dem Kellner ist rot.
'The waiter's bell/the bell of the waiter is red.'

Two experimental lists were created, such that in each list, the confederate used each of the two genitive structures 12 times and for different items in the two lists. Items appeared in a pseudo-randomized order, in which there were always between one and three filler

trials between two experimental trials. To control for any effects of the specific order, about half of the participants received the items in reverse order.

The descriptions of the verification picture were wrong in half of the cases and correct in the other half. For the experimental items, wrong descriptions always consisted of the confederate naming the wrong color. For the filler items where one character was colored, the wrong description always consisted of the confederate naming the wrong character (e.g., "The biker is blue", for a picture with a blue hunter and a black and white biker). This was done to ensure that participants could not predict whether the color of the object or the object itself was wrongly identified in the wrong descriptions, which presumably should enhance the motivation to use precise descriptions, and hence, possessive structures for the experimental items. Finally, for the filler items where the elicitation picture consisted in two colored characters, the wrong descriptions always consisted of wrongly identifying the color, as was the case in the experimental items. Moreover, the confederate answered with "yes" to half of the descriptions of the participant and with "no" to the other half, with both types of answers being equally likely both for filler and experimental items.

In the pretest and the post-test phase, for the experimental items, we used six different characters and 12 different objects. As in the priming phase, the six characters chosen for the pre- and post-test could be described by masculine, disyllabic nouns in German. These nouns fell in frequency classes 9–12 according to the *Projekt Deutscher Wortschatz*, had the same mean frequency (10.83), and all ended with the suffix *–er* and formed the genitive form by adding the suffix *–s*. The objects could be labeled by 12 different nouns, 4 of them belonging to each of the three genders. Six of these nouns were disyllabic and six were monosyllabic. The pictures of the description set were constructed following the same principles as were applied for the construction of the pictures presented during the priming phase. Each character appeared twice on the pictures holding the colored object and twice not holding the colored object, and an equal number of times at the left and at the right side of the screen. As no priming was intended during this phase, the verification pictures were constructed as were the filler pictures. That is, they always displayed two characters without any objects, and in half of the cases, one character was completely colored, while in the other half, both were colored. All characters appeared equally often in these verification pictures, and the four characters of one experimental item (verification and elicitation picture combined) were always different from each other. All four colors appeared an equal number of times in the verification pictures and the description pictures, and half of the confederate's descriptions were correct, while the other half were wrong. Each character appeared twice in the description picture holding the colored object and twice not holding the colored object. For the filler items, we used the same six characters and combined them such that there was an equal number of filler pictures with one colored character and both characters being colored, and all four possible combinations of elicitation and verification picture (one person colored/both persons colored, etc.) appeared equally often. All materials, as well as the data to be reported below and statistical analysis scripts, can be accessed at the study's OSF page.

4.3. Procedure

All experimental sessions were conducted with an experimenter, a naïve participant, and a confederate participant. The naïve participant was not aware of the confederate's role until after the completion of the experiment.

The naïve participant and the confederate were sitting opposite to each other, such that each of them could see his or her own screen but only the back of the opposite screen, and it was thus impossible for the participant to see that the confederate was reading the descriptions and judgments, instead of making them spontaneously. The experimenter sat such that she could observe both participant and confederate. Sessions were recorded for the post-experimental coding of responses.

At the beginning of the experimental session, the participants gave written consent to participating. Next, the training phase began. The two participants each saw an identical

PowerPoint presentation with the six characters and 12 objects used during the pretest and post-test phase, with a written sentence introducing the label for the respective character or object ("This is the…"). The experimenter read the sentences out loud. The naïve and confederate participants were instructed to look at each of the characters and objects carefully and to try to remember the label, but were also assured that they could use other labels during the experiment if they could not remember the one presented during the training phase. They were then informed that the purpose of the experiment was to investigate the descriptions of the pictures, and that they were going to describe the pictures in turn and judge whether the pictures they saw matched the description just given by the other participant or not. They were told to describe their pictures as quickly and accurately as possible, and to make the judgment whether their picture matched the description by saying *ja* ('yes') or *nein* ('no'), and to proceed to the following picture after each description or judgment by pressing the space bar. The pictures that the participant saw were presented in a PowerPoint presentation on the laptop screen, while the confederate speaker saw the same pictures with the expected descriptions, as well as the 'yes' or 'no' judgments, from a PowerPoint presentation on her laptop.

After the pretest phase, there was a new training session for the priming phase, where participants were presented with the 12 characters and the 48 objects used during the priming phase in the same way as described for the pretest phase, before completing the priming session.

They could then look once more at the characters and objects for the post-test phase (that were identical to the pretest), before completing this phase.

Following the priming experiment, all participants completed a background questionnaire asking for their age, their gender, and their language-learning history. Finally, they were paid for their participation and were fully informed about the purpose of the experiment.

5. Results

All target answers produced by the participants were coded as structures containing postnominal genitives ("genitive"), *von*-phrases ("von"), or other responses ("other"). Other structures often included cases where the possessive relation was expressed as a predicative, as in *Der Künstler hat eine rote Rose.* ('the artist has a red rose').

5.1. Descriptive Results

Table 1 displays the absolute numbers of genitives, *von*-phrases, and other responses produced in the pretest, in the two conditions of the priming phase, and in the post-test. Note that there is a large number of other responses, in particular in the pretest. While the inferential statistics will be conducted on a dataset from which the other responses were excluded, to give a complete picture, Table 1 displays percentages for the two critical structures, both when the other responses are excluded and when they are not excluded.

Table 1. Total numbers of other responses, genitive responses, and *von*-phrase responses in the three phases of the experiment, as well as percentages of genitives and *von*-phrases with other responses included or excluded in the total count.

	Total Other	**Total Gen.**	**Total *von***	**% gen. (Others Incl.)**	**% *von* (Others Incl.)**	**% gen. (Others Excl.)**	**% *von* (Others Excl.)**
Pretest	336	106	38	22.08	7.92	73.61	26.39
Priming (gen. primes)	89	369	22	76.88	4.58	94.37	5.63
Priming (*von* primes)	93	235	152	48.96	31.67	60.72	39.28
Post-test	127	320	33	66.67	6.88	90.66	9.35

These data show that, while both genitives and *von*-phrases are initially less frequent than other responses, the genitive structure is used relatively more often than the *von*-phrase structure at pretest (at a ratio of about 74 to 26%). During the priming phase, the production rate of genitives increases after genitive primes (from about 74% to about 93%, when other responses are excluded), while it decreases after *von*-phrase primes (from about 74% to about 61%, when other responses are excluded). During the post-test, the genitive is the prevalent structure, both when other responses are included in the count (about 67% genitives) and when they are excluded (about 91% genitives). This means that the genitive structure gains in production rates during the experiment, both in comparison to the alternative *von*-phrase structure and in comparison to other responses, which are produced at marginal rates at post-test. As these numbers give no insights into the temporal development of production rates during the priming phase, Figure 2 plots the percentage of genitives across the trials of the priming phase.[1] Other responses have been excluded from this count. The regression line indicates a gradual increase in genitive responses and implies a complementary decrease in the rate of the alternative *von*-phrase.

Figure 2. Percentage of genitive responses (out of all genitives and *von*-phrases produced during the priming phase) per order of appearance of the experimental items during the priming phase. The straight line represents a regression line.

5.2. Inferential Analyses

We restricted the inferential analyses to the two alternative structures that we had aimed at eliciting, e.g., genitives and *von*-phrases; that is, we excluded all structures that were coded as "other" from the data analyses that are reported in the following.

In a first step, we tested whether there was a significant priming effect during the priming phase. We computed a logistic mixed-effects model with "Target" (genitive, coded as "1" vs. *von*-phrase, coded as "0") as the dependent variable and "Condition" (genitive vs. *von*-phrase) as the independent variable. In addition, we included the factor "Order" (referring to the order of experimental trials during the priming phase), which was centered and scaled, as well as its interaction with "Condition". All analyses were conducted using the Lme4 (Bates et al. 2015) and lmerTest (Kuznetsova et al. 2017) packages in R (R Core Team 2022). "Condition" was sum-coded using the contr.sum function. Table 2 summarizes the model output.

Table 2. Output of generalized mixed-effects model for priming phase.

	Estimate	Std. Error	z Value	Pr (>|z|)
(Intercept)	3.10	0.57	5.40	<0.001 ***
Condition	−2.24	0.24	−9.33	<0.001 ***
Order	0.50	0.19	2.66	<0.01 **
Condition: Order	0.36	0.19	1.90	0.06.

Note: Formula: glm(target~condition ∗ order + (1 | participant)). Note that the model does not include the random intercept of item, because models with both intercepts or with only the random intercept of item yielded singular fits. ** indicates a *p*-value of <0.01, *** indicates a *p*-value of <0.001.

There was a main effect of Condition, indicating that the use of each of the target structures increased in the respective priming conditions. There also was a main effect of Order, which indicated the cumulative priming of one structure (genitives) at the expense of the other (*von*-phrases). This main effect was qualified by a marginal interaction between Condition and Order, however. As it seems premature to interpret the main effect of Order without exploring how it may be qualified by the interaction with Condition, Figure 3 displays the development of production rates separately for the "genitive" and the "*von*-phrase" priming conditions. Again, for better readability, the graph only plots the percentage of genitive structures, which is complementary to the percentage of *von*-structures.

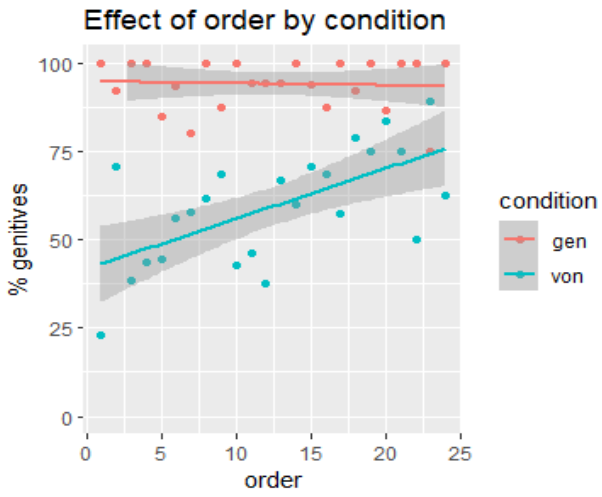

Figure 3. Percentage of genitives for the two priming conditions per experimental trial number during the priming phase. Other responses have been excluded. The straight lines represent regression lines.

These data show that, in the genitive priming condition, the target structures are produced at extreme ranges, with virtually no changes over time. It seems that genitive responses reach the ceiling from the start, leaving no possibility of a further increase relative to the alternative structure. The picture for the *von*-phrase priming condition is different. In this condition, genitive target responses start with a relatively lower production rate than the *von*-phrases and become increasingly frequent over the course of the experiment.

In a second step, we aimed at testing effects over time, by comparing the relative amount of genitive and *von*-phrase structures at pretest to the relative amounts in the two priming conditions during the priming phase, and to the relative amount at post-test. We combined the datasets from pretest, priming phase, and post-test, and defined a new independent variable "Phase" with the four levels "Pretest", "Priming phase (genitive primes)", "Priming phase (*von*-phrase primes)", and "Post-test". "Pretest" was set as the reference level to which the three other levels were compared, applying treatment coding. The dependent variable was the target structure, with *von*-phrases being coded as 0 and genitives as 1. Importantly, defining each of the two priming levels as a separate level

that can be compared to the pretest allows for exploring (inverse) preference effects. The comparison between the "pretest" and the "priming phase (genitive primes)" levels directly compares the change in the relative production rate of genitives and *von*-phrases from the pretest to this priming condition, and hence, assesses the effect of genitives as primes. The comparison between the "pretest" and the "priming phase (*von*-phrase primes)" levels assesses the effect of *von*-phrases as primes. Given that genitives are more frequent than *von*-phrases in the pretest, an inverse preference effect would mean that there should be priming by *von*-phrase primes but no, or lesser, priming by genitive primes. The results are summarized in Table 3.

Table 3. Output of generalized mixed-effects model for pretest, two priming conditions, and post-test (outcome: genitive vs. *von*-phrases).

	Estimate	Std. Error	z Value	Pr (>|z|)
(Intercept)	1.26	0.59	2.13	<0.05 *
Phase (pretest vs. priming-gen)	3.95	0.48	8.17	<0.001 ***
Phase (pretest vs. priming-*von*)	−0.35	0.33	−1.07	0.29
Phase (pretest vs. post-test)	2.51	0.38	6.62	<0.001 ***

Note: Formula: glm(target~phase + (1|participant)). Note that the model does not include the random intercept of item, because a model with both intercepts and a model with the random intercept of item only yielded singular fits. * indicates a *p*-value of <0.05, *** indicates a *p*-value of <0.001.

Importantly, the increase in the rate of genitive production relative to the pretest that is caused by the genitive prime condition is statistically significant, while the increase in the rate of *von*-phrases caused by the *von*-phrase priming condition (reflected in the negative estimate) is numerically weaker and not significant. This is not compatible with an inverse preference effect, which would have predicted stronger priming of the less frequent structure. In addition, the advantage of the more frequent structure, the genitive, persists in the post-test, as reflected in the significant difference in the rate of genitives between pretest and post-test.

6. Discussion

To sum up our results, our pretest data show that, as expected, postnominal genitives were more frequent than *von*-phrases, which is in line with the corpus data (Kopf 2021; Kopf and Weber 2022; Smith 2003). Crucially, the incidence of genitive responses was boosted by the priming manipulation. Genitives were the prevalent structure in the priming phase, and their high production rate was maintained during the post-test. We interpret the difference between the rates at the pretest and rates during priming as evidence of a preference effect. This observation complements the previous findings of inverse preference effects (e.g., Jaeger and Snider 2013; Kaschak 2007; Scheepers 2003), suggesting that both patterns can occur and that further factors will need to be taken into account, to understand whether the lesser or the more frequent structure will lead to relatively stronger priming, as discussed in more detail at the end of the Discussion session.

Second, a closer inspection of responses in the priming phase reveals how production rates changed over time. An effect of the priming manipulation is visible from the very first trial onward. Across the trials, the proportion of genitive responses increased relative to the *von*-phrase. This pattern of results is indicative of a cumulative priming of the prevalent construction. To better understand this effect, it is informative to look at it separately by condition. For genitive primes, genitive responses were immediately boosted to ceiling, with no changes over the trials and therefore no chance of cumulative priming. For *von*-primes, the picture is more complex. In the first trials, *von*-responses were descriptively more frequent than the generally preferred genitive structures, but the rate of *von*-responses soon decreased below that of genitive responses. Since the primes and accumulating responses differed in structure, this effect cannot be attributed to priming by the immediately preceding input. It seems plausible to assume that cumulative priming of the genitive construction was involved in the dynamics of the *von*-prime trials, most

probably by participants priming themselves by the repeated production of the prevalent genitive structure throughout the priming phase (cf. Jacobs et al. 2019). Since the structures are complementary, it is not easy to discern potentially conflicting effects, and we cannot say whether we found evidence for error-based learning of the less preferred structure or not. But we may assume that we found cumulative priming of the preferred structure. A likely explanation of the cumulative priming of the initially preferred structure seems to be that the use of a dominant structure reinforces itself, because, presumably, participants are not only primed by the utterances produced by the confederate but also by the utterances that they themselves produce. This explains why the dominance of the preferred structure increases throughout the priming phase and does not fall back to pretest levels at post-test. It leaves open the question why other studies have found inverse preference effects and have often not found cumulative priming in favor of the more frequent structure, to which we turn in the following.

The mechanism underlying inverse preference effects is assumed to operate on comprehended input in general (cf. Jaeger and Snider 2013) and, more specifically, on primes presented in an experiment. It may be envisaged as has been modeled in error-based learning approaches (cf. Chang et al. 2006; Dell and Chang 2014) or in expectation adaptation models based on surprisal (cf. Jaeger 2010; Jaeger and Snider 2013). In the following, we stick to a simplified version of the error-based learning approach. During comprehension, the mechanisms recur to transition probabilities between words that are based on previous input. These are accessed by the production system to generate predictions on the unfolding structure. A mismatch between word-wise predictions and the structure at hand causes a prediction error that is fed back to tune structural representations. This purely input-based mechanism accountss for implicit learning and for inverse preference effects in structural priming. The initial increase in *von*-phrases in the *von*-priming condition might be an incidence of error-based learning, but if there is such an effect, it is clearly weaker than the priming effect boosting genitives. Moreover, genitives continue to be boosted throughout the priming phase, with a complementary decrease in *von*-phrases. This cannot be explained by the error-based mechanism, because within the error-based model, there is no additional mechanism that might account for cumulative preference effects. The short-lived lexical boost in structural priming is ascribed to the explicit memorization of word forms (Chang et al. 2006), irrespective of their phrasal status (heads or no heads). As the lexical boost for attributed noun phrases has been shown to hinge on the repetition of nouns (Cleland and Pickering 2003) and nouns were not repeated between primes and targets in our experiment, an explicit memory account of the attested cumulative preference effects is not plausible either, which is why we turn to hybrid models.

Hybrid models, such as the one proposed by Reitter et al. (2011), propose a second mechanism, next to underlying error-based learning, to account for short-lived priming effects. This mechanism tends to be envisaged in terms of the residual activation model proposed by Pickering and Branigan (1998) (cf. Jaeger and Snider 2013; Reitter et al. 2011). Every time a structure is processed, its activation and therefore its probability of being produced again increases. This mechanism accounts for the lexical boost in structural priming, but it is also capable of accounting for effects of abstract structural priming. Contrary to the error-based mechanism, it is not only sensitive to priming by the input but also to priming by previously produced output, thus bringing conservativity (as opposed to learning) into the system. The mechanism captures alignment with the interlocutor (Branigan et al. 2000) and self-priming (Jacobs et al. 2019). We propose that assuming such an activation-based mechanism has the potential to account for preference effects, as well as for the cumulative priming of an initially preferred structure. If structures are produced repeatedly, the respective representations accumulate activation and their opportunity to decay decreases (cf. Reitter et al. 2011). Importantly, according to this model, the representations linked to the less frequent structure of course receive activation as well, every time it is produced, but as the more frequent structure is produced more frequently, effects for this structure should reinforce themselves to a stronger degree than for the less

frequent structure. As for the temporal persistence of preference effects till a post-test, whether these are to be expected is, to our knowledge, not explicitly addressed by the existing hybrid models. We found an effect that survived till a post-test that immediately followed the priming phase. Recent evidence suggests that structural priming may affect preferences over longer time intervals such as one week (Kaschak et al. 2011), and that inverse preference effects persist even one month after the experimental manipulation (Heyselaar and Segaert 2022). Future research will show whether preference effects survive longer time periods without priming or whether they are dependent on conditions where they can continuously renew themselves.

The assumption of two competing mechanisms, error-based learning in addition to an activation-based mechanism, calls for an account of their interaction. The relative weight of the two mechanisms must be different in different situations, as evidenced by conflicting findings of both preference and inverse preference effects in the literature. Which mechanism is prevalent in any specific situation may depend on several factors. Given that, compared to the biases looked at in most previous studies, the bias for genitives we focused on was a rather strong one, we suspect that the relative frequency of the structures to be produced should be considered as one important issue. Both accumulating activation and prediction errors are assumed to be sensitive to the initial frequency distribution, but the way in which they change depending on frequencies need not be similar, and their respective changes could follow different, potentially non-linear, trajectories. This makes it hard to predict a tipping point at which either the accumulation of activation—which works in favor of the more frequent structure—or prediction error—which works in favor of the less frequent structure—outweighs the other process. More evidence is needed concerning distributional effects, therefore it will be important to vary the constructions presented in future priming experiments, both within and across languages.

As a further, more speculative avenue of future research, it may also seem worthwhile to explore why structures differ in frequency in the first place. If a structure is much more frequent than an alternative structure, this may indicate that the two structures are in fact no true alternatives. The *von*-phrase is a marginal structure for the specific type of attributive noun phrase that we looked at (appellative noun phrases containing a case-marked article). Speakers may perceive the less frequent structure as not appropriate in this morphosyntactic context, and this may lower production rates. To take this one step further, it is also possible that whether a structure is perceived as a viable alternative depends on the social context. One reason why the *von*-structure was rare in our experimental setting could be that it is often assumed to be more frequently used in informal settings. It is possible that this may have contributed to the gradual decrease in its use during the experiment, as participants may have increasingly adapted to the formal setting of an experiment[2]. These ideas suggest a more complex interplay between knowledge about possible constraints, built up by long-term experience, and short-term experiences in an experiment, than one may expect when taking models of syntactic priming at face value. In particular, it is possible that explicit processes related to language attitudes (such as which type of structure is expected in which setting) interact with underlying implicit processes, be they based on activation or prediction error. This possibility could be further explored in future studies that could attempt to systematically study effects of register.

7. Prospects

While we have observed some important patterns, we do not think that our evidence allows for firm conclusions about different models of priming, but they help us to ask precise questions in order to gather more conclusive evidence. In particular, the conditions under which preference and inverse preference effects arise need further investigation: Is it possible to identify frequency ranges that constrain the development of cumulative priming? To which extent is lexical information involved in the rise in preference and inverse preference effects? Are the units involved in preference and inverse preference effects identical or do they differ? Might differences in cumulative structural priming

between younger and older speakers (Heyselaar and Segaert 2022) be accounted for by an input-based mechanism ceasing to interfere with the residual activation mechanism across the lifespan (cf. Chang et al. 2006)?

To understand language learning, it would be beneficial to look more closely at the relations between the influence of prior experience (e.g., what is the baseline frequency of a given structure) and the experience within an experiment (cf. Jaeger and Snider 2013). With regard to possessive constructions, one interesting avenue for future research would be to look at whether priming effects for the structures tested here play out differently for speakers who may have less knowledge of the subtle factors governing the choice between the genitive and the *von*-phrase, such as children who are in the process of acquiring German and might have had less exposure to complex noun phrases such as the ones we looked at here, as well as second-language learners of German.

More generally, the mechanisms underlying inverse preference and preference effects have the potential to account for individual differences in learning and fossilization during second-language acquisition. The combination of a priming phase with a pretest and a post-test phase, used in cumulative priming studies, corresponds to a standard design in intervention research (cf. Ionin and Montrul 2023), paving the way for a more extensive use of the paradigm in second-language research. Taking advantage of frequency ranges that constrain preference and inverse preference effects, intervention studies thus might help to identify an optimally skewed input for implicit learning (cf. Goldberg and Casenhiser 2008; McDonough and Trofimovich 2013).

Author Contributions: Conceptualization, S.S. and S.P.; methodology, S.S. and S.P; formal analysis, S.S. and S.P.; writing-original draft preparation, S.S. and S.P.; writing-review and editing, S.S. and S.P.; visualization, S.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The original data presented in the study are openly available via the *Open Science Framework* at DOI 10.17605/OSF.IO/VJ6RA.

Acknowledgments: We would like to thank all (former) students involved in stimuli preparation and data collection, as well as the anonymous reviewers who provided detailed and constructive feedback.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Appendix A.1. Experiment on Pre- vs. Postnominal Genitives

In an additional experiment, we compared prenominal (example A1) to postnominal (example A2) genitive constructions. Prenominal genitive constructions are frequent when the attributive noun phrase is a proper name but have all but disappeared from modern German for attributive appellative nouns. Prenominal genitive structures with appellative nouns are thus exceedingly rare, mainly occurring in fixed expressions, and have an archaic flavor.

(A1) Genitive construction, prenominal:

Des	*Gärtner-s*	*Hut*	*ist rot.*
the.GEN	gardener-GEN	hat	is red

(A2) Genitive construction, postnominal:

Der	*Hut*	*des*	*Gärtner-s*	*ist rot.*
the.NOM	hat	the.GEN	gardener-GEN	is red

Appendix A.2. Method

Appendix A.2.1. Participants

Sixteen native speakers of German (14 female, 2 male, mean age: 25, range: 22–29) participated in the experiment. All of them were students at the University of Münster, and none of them were bilingual as a child.

Appendix A.2.2. Materials and Procedure

The materials and procedure of this experiment were identical to those of the experiment described in the main text of the paper (referred to as the "gen/*von* experiment" in the following), except that all *von*-phrases used in the priming stimuli of the gen/von experiment were replaced by prenominal genitive attributes (e.g., *des Künstlers Rose ist rot*).

Appendix A.3. Results

All target answers produced by participants were coded as structures containing postnominal genitives, prenominal genitives, or other structures. Other structures included cases where the possessive relation was expressed as a predicative, as in *Der Gärtner hat einen blauen Keks* ('the gardener has a blue cookie').

Appendix A.3.1. Descriptive Results

Table A1 displays the absolute numbers of postnominal and prenominal genitives and other responses produced in the pretest, in the two conditions of the priming phase, and in the post-test. Moreover, Table A1 displays percentages for the two critical structures, both when other responses are excluded and when they are not excluded.

Table A1. Total numbers of other responses and post- and prenominal genitive responses in the three phases of the experiment, as well as percentages of post- and prenominal genitives, with other responses included or excluded in the total count.

	Total Other	**Total Postn. Gen.**	**Total Pren. Gen.**	**% postn. (Others Incl.)**	**% pren. (Others Incl.)**	**% postn. (Others Excl.)**	**% pren. (Others Excl.)**
Pretest	157	35	0	18.23	0	100	0
Priming (postn. primes)	28	162	2	65.63	1.04	98.78	1.22
Priming (pren. primes)	48	117	27	60.94	14.06	81.25	18.75
Post-test	58	134	0	69.79	0	100	0

These data show that there are no occurrences of the prenominal genitive at pretest. The rate of postnominal genitives (18%) is slightly lower than in the gen/*von* experiment (22%). If the analysis is restricted to the two critical structures, postnominal genitives show a slight decrease after postnominal genitive primes during the priming phase (from 100% to about 99%, when other responses are excluded), and a stronger decrease after prenominal primes (to about 81%; again, other responses being excluded). During post-test, there are no further instances of prenominal genitives. The postnominal genitive is thus prevalent (100% when only the two critical structures are considered and 70% when all structures are considered). The temporal development of the percentage of postnominal genitives is displayed in Figure A1, which suggests no change in the high rate of postnominal genitives during the priming phase.

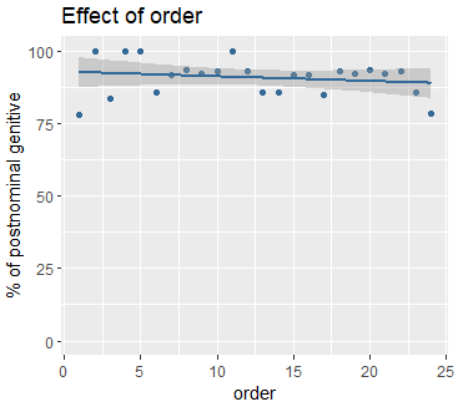

Figure A1. Percentage of postnominal genitives (out of all pre- and postnominal genitives produced during the priming phase) per order of appearance of the experimental items during the priming phase. The straight line represents a regression line.

Appendix A.3.2. Inferential Analyses

To test whether there was a significant priming effect during the priming phase, we computed a logistic mixed-effects model with Target (postnominal genitive, coded as "1" vs. prenominal genitive, coded as "0") as the dependent variable and "Condition" (prenominal vs. postnominal genitive) as the independent variable. In addition, we included the factor "Order" (referring to the order of experimental trials during the priming phase), which was centered and scaled, as well as its interaction with "Condition". "Condition" was sum-coded using the contr.sum function. Table A2 summarizes the model output.

Table A2. Output of generalized mixed-effects model for priming phase.

	Estimate	Std. Error	z Value	Pr (>|z|)
(Intercept)	5.99	1.30	4.61	<0.001 ***
Condition	−2.57	0.67	−3.83	<0.001 ***
Order	−0.34	0.54	−0.64	0.55
Condition: Order	0.62	0.54	1.16	0.25

Note: Formula: glm(target~condition ∗ order + (1 | participant) + (1 | item). *** indicates a *p*-value of <0.001.

The main effect of Condition indicates that the use of each of the target structures increased in the respective priming conditions. There was no main effect of Order or interaction with Condition, suggesting that this priming effect did not change during the priming phase. For the purpose of comparison with the gen/von-experiment, Figure A2 nevertheless plots the temporal development separately for the two priming conditions. It plots the percentage of postnominal genitives, which is complementary to the percentage of prenominal genitives, as the analysis has been restricted to these two cases.

This figure confirms that, as suggested by the inferential statistics, there was almost no discernable temporal development of the priming effect over time at all. As there were no instances of prenominal genitives in the pretest or post-test, we did not conduct any analyses across phases.

Figure A2. Percentage of postnominal genitives for the two priming conditions per experimental trial number during the priming phase (out of all pre- and postnominal genitives). The straight lines represent regression lines.

Appendix A.4. Discussion

To sum up, we found a priming effect for pre- and postnominal genitives. The occurrence of prenominal genitives during the priming phase may at first sight be taken to reflect an inverse preference effect, because, while the relative amount of postnominal genitives did not increase when comparing the pretest to priming, the relative amount of prenominal genitives did increase. We are reluctant to draw this conclusion, however, because the baseline of a 100% postnominal genitives necessarily allows for one direction of change only. Note also that, when other responses are taken into account, the absolute increase between the pretest and the respective priming condition was greater for postnominal genitives than for prenominal genitives (from about 18% to about 66%, compared to from 0% to about 14%), and that the increase for prenominal genitives did not survive till post-test at all. Given these conflicting trends, we think that, while we can conclude that there was priming, no conclusions about the relative strength of the two priming conditions (e.g., inverse preference or preference effects) are warranted.

As for the temporal development during the priming phase, postnominal genitives clearly are at ceiling in the postnominal genitive priming condition, leaving no room for a further increase. As for the prenominal genitive priming condition, there would be room for a further increase of either of the structures, but there is no development. It is possible that error-based learning effects, which should give a relative boost to the prenominal construction, and activation-based effects, which should accumulate for the more frequent postnominal construction, are in balance here, but as this interpretation hinges on an absence of any temporal development, and thus ultimately on null effects, more direct evidence for both of the presumed processes would be necessary to substantiate it. Moreover, if the production of prenominal genitives during the priming phase is explained by error-based learning, an additional explanation is needed to account for the fact that it is no longer produced at post-test. One possibility is that speakers may perceive the archaic structure as ungrammatical and may be reluctant to produce it for this reason. To explore this possibility, we tested possessive constructions in a grammaticality rating task (1: fully ungrammatical, 7: fully grammatical) with grammatical and ungrammatical fillers. Results from 18 native speakers of German and 18 experimental items (6 per condition, distributed across three different experimental lists) indicate that the postnominal genitive (median 7, mean 6.6) and the prenominal genitive (median 7, mean 6.2) were perceived as more grammatical than the *von*-phrase items (median 6, mean 5.4). Thus, the low production rate of prenominal genitives was presumably not due to reluctance to produce ungrammatical responses, even though it may nevertheless play a role that these structures

may be perceived, if not as ungrammatical, then certainly as old-fashioned. To sum up, this experiment shows that both pre- and postnominal genitives can be primed, but that only the postnominal genitive survives till post-test. The results do not rule out an account in terms of hybrid models of priming as proposed in the text, but they do not provide any direct evidence for it either. In addition, the absence of prenominal genitives in the post-test seems to present a puzzle for any model and may be related to the archaic nature of this structure.

Appendix B

List of experimental items in the priming phase. Examples 1 and 3 (postverbal genitive and *von*-phrase) were primes in the experiment reported in the main text of the paper, while Examples 1 and 2 (postverbal and preverbal genitive) were primes in the experiment reported in Appendix A.

Verification Picture	**Confederate's Utterance**	**Elicitation Picture**
Left: Kellner mit roter Glocke Right: Radler mit Glocke	*Die Glocke des Kellners/Des Kellners Glocke/Die Glocke von dem Kellner ist rot.*	Left: Künstler mit roter Rose Right: Fischer mit Rose
Left: Fischer mit roter Krone Right: Künstler mit Krone	*Die Krone des Fischers/Des Fischers Krone/Die Krone von dem Fischer ist rot.*	Left: Radler mit roter Tasse Right: Kellner mit Tasse
Left: Gärtner mit roter Brille Right: Ritter mit Brille	*Die Brille des Gärtners/Des Gärtners Brille/Die Brille von dem Gärtner ist gelb.*	Left: Priester mit roter Fahne Right: Priester mit Fahne
Left: Schwimmer mit roter Feder Right: Priester mit Feder	*Die Feder des Schwimmers/Des Schwimmers Feder/Die Feder von dem Schwimmer ist gelb.*	Left: Ritter mit roter Kerze Right: Gärtner mit Kerze
Left: Maurer mit roter Zwiebel Right: Schäfer mit Zwiebel	*Die Zwiebel des Maurers/Des Maurers Zwiebel/Die Zwiebel von dem Maurer ist rot.*	Left: Jäger mit roter Blume Right: Sportler mit Blume
Left: Sportler mit roter Puppe Right: Jäger mit Puppe	*Die Puppe des Sportlers/Des Sportlers Puppe/Die Puppe von dem Sportler ist rot.*	Left: Schäfer mit roter Schere Right: Maurer mit Schere
Left: Radler mit Muschel Right: Kellner mit gelber Muschel	*Die Muschel des Kellners/Des Kellners Muschel/Die Muschel von dem Kellner ist grün.*	Left: Fischer mit Gabel Right: Künstler mit gelber Gabel
Left: Künstler mit Pfeife Right: Fischer mit gelber Pfeife	*Die Pfeife des Fischers/Des Fischers Pfeife/Die Pfeife von dem Fischer ist grün.*	Left: Kellner mit Säge Right: Radler mit gelber Säge
Left: Ritter mit Ring Right: Gärtner mit gelbem Ring	*Der Ring des Gärtners/Des Gärtners Ring/Der Ring von dem Gärtner ist gelb.*	Left: Schwimmer mit Stein Right: Priester mit gelbem Stein
Left: Priester mit Stock Right: Schwimmer mit gelbem Stock	*Der Stock des Schwimmers/Des Schwimmers Stock/Der Stock von dem Schwimmer ist gelb.*	Left: Gärtner mit Topf Right: Jäger mit gelbem Topf
Left: Schäfer mit Knopf Right: Maurer mit gelbem Knopf	*Der Knopf des Maurers/Des Maurers Knopf/Der Knopf von dem Maurer ist rot.*	Left: Sportler mit Korb Right: Ritter mit gelbem Korb
Left: Jäger mit Helm Right: Sportler mit gelbem Helm	*Der Helm des Sportlers/Des Sportlers Helm/Der Helm von dem Sportler ist rot.*	Left: Maurer mit Pfeil Right: Schäfer mit gelbem Pfeil
Left: Priester mit blauem Kamm Right: Fischer mit Kamm	*Der Kamm des Priesters/Des Priesters Kamm/Der Kamm von dem Priester ist blau.*	Left: Schwimmer mit blauem Pilz Right: Künstler mit Pilz
Left: Ritter mit blauem Schuh Right: Kellner mit Schuh	*Der Schuh des Ritters/Des Ritters Schuh/Der Schuh von dem Ritter ist blau.*	Left: Gärtner mit blauem Keks Right: Radler mit Keks
Left: Jäger mit blauem Spiegel Right: Schwimmer mit Spiegel	*Der Spiegel des Jägers/Des Jägers Spiegel/Der Spiegel von dem Jäger ist grün.*	Left: Sportler mit blauem Koffer Right: Priester mit Koffer
Left: Schäfer mit blauem Hammer Right: Gärtner mit Hammer	*Der Hammer des Schäfers/Des Schäfers Hammer/Der Hammer von dem Schäfer ist grün.*	Left: Maurer mit blauem Knochen Right: Ritter mit Knochem

Verification Picture	Confederate's Utterance	Elicitation Picture
Left: Künstler mit blauem Glas Right: Sportler mit Glas	*Das Glas des Künstlers/Des Künstlers Glas/Das Glas von dem Künstler ist blau.*	Left: Fischer mit blauem Brot Right: Jäger mit Brot
Left: Radler mit blauem Nest Right: Maurer mit Nest	*Das Nest des Radlers/Des Radlers Nest/Das Nest von dem Radler ist blau.*	Left: Kellner mit blauem Ei Right: Schäfer mit Ei
Left: Schwimmer mit Bett Right: Künstler mit grünem Bett	*Das Bett des Künstlers/Des Künstlers Bett/Das Bett von dem Künstler ist blau.*	Left: Priester mit Schiff Right: Fischer mit grünem Schiff
Left: Gärtner mit Kreuz Right: Radler mit grünem Kreuz	*Das Kreuz des Radlers/Des Radlers Kreuz/Das Kreuz von dem Radler ist blau.*	Left: Ritter mit Blatt Right: Kellner mit grünem Blatt
Left: Sportler mit Pferd Right: Priester mit grünem Pferd	*Das Pferd des Priesters/Des Priesters Pferd/Das Pferd von dem Priester ist grün.*	Left: Jäger mit Rad Right: Schwimmer mit grünem Rad
Left: Maurer mit Fass Right: Ritter mit grünem Fass	*Das Fass des Ritters/Des Ritters Fass/Das Fass von dem Ritter ist grün.*	Left: Schäfer mit Brett Right: Gärtner mit grünem Brett
Left: Fischer mit Schwein Right: Jäger mit grünem Schwein	*Das Schwein des Jägers/Des Jägers Schwein/Das Schwein von dem Jäger ist gelb.*	Left: Künstler mit Schaf Right: Sportler mit grünem Schaf
Left: Kellner mit Auto Right: Schäfer mit grünem Auto	*Das Auto des Schäfers/Des Schäfers Auto/Das Auto von dem Schäfer ist gelb.*	Left: Radler mit Messer Right: Maurer mit grünem Messer

List of experimental items in the pretest and post-test phases.

Verification Picture	Confederate's Utterance	Elicitation Picture
Left: roter Förster Right: Räuber	*Der Räuber ist rot.*	Left: Läufer mit rotem Schlüssel Right: Maler
Left: roter Räuber Right: Förster	*Der Förster ist rot.*	Left: Maler mit roter Bombe Right: Läufer
Left: Tänzer Right: roter Bäcker	*Der Tänzer ist rot.*	Left: Förster mit roter Nadel Right: Räuber
Left: Bäcker Right: blauer Tänzer	*Der Bäcker ist blau.*	Left: Räuber mit blauer Geige Right: Förster
Left: grüner Läufer Right: Maler	*Der Läufer ist grün.*	Left: Tänzer Right: Bäcker mit grünem Besen
Left: grüner Maler Right: Läufer	*Der Maler ist grün.*	Left: Bäcker Right: Tänzer mit grüner Maus
Left: grüner Förster Right: grüner Räuber	*Der Förster und der Räuber sind grün.*	Left: Läufer Right: Maler mit grünem Brief
Left: gelber Räuber Right: gelber Förster	*Der Räuber und der Förster sind gelb.*	Left: Maler Right: Läufer mit gelbem Hut
Left: gelber Tänzer Right: gelber Bäcker	*Der Tänzer und der Bäcker sind gelb.*	Left: Förster Right: Räuber mit gelbem Herz
Left: gelber Bäcker Right: gelber Tänzer	*Der Tänzer und der Bäcker sind blau.*	Left: Räuber Right: Förster mit gelbem Eis
Left: blauer Läufer Right: blauer Maler	*Der Läufer und der Maler sind blau.*	Left: Tänzer mit blauem Huhn Right: Bäcker
Left: blauer Maler Right: blauer Läufer	*Der Maler und der Läufer sind gelb.*	Left: Bäcker mit blauem Kissen Right: Tänzer

Notes

[1] Following the suggestion of an anonymous reviewer, we have conducted additional analyses of order effects in which we did not enter the order of experimental trials into the model, but the number of times participants had heard each of the

two structures. For both the experiment reported in the main text and the one reported in the Appendices A and B, we found qualitatively identical effects to an effect of order, and therefore decided to keep this factor as an aggregated measure of exposure to both structures.

[2] We thank an anonymous reviewer for this suggestion.

References

Bates, Douglas, Martin Maechler, Ben Bolker, and Steven Walker. 2015. Package Lme4: Linear Mixed-Effects Models Using Eigen and S4. *Journal of Statistical Software* 67: 1–48. [CrossRef]

Bernolet, Sarah. 2008. Lexical-Syntactic Representations in Bilingual Sentence Production. Ph.D. thesis, Ghent University, Ghent, Belgium.

Bernolet, Sarah, and Robert J. Hartsuiker. 2010. Does verb bias modulate syntactic priming? *Cognition* 114: 455–61. [CrossRef] [PubMed]

Bernolet, Sarah, Robert J. Hartsuiker, and Martin J. Pickering. 2013. From language-specific to shared syntactic representations: The influence of second language proficiency on syntactic sharing in bilinguals. *Cognition* 127: 287–306. [CrossRef]

Bock, J. Kathryn. 1986. Meaning, sound, and syntax: Lexical priming in sentence production. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 12: 575–86. [CrossRef]

Bock, J. Kathryn, and Anthony S. Kroch. 1989. The isolability of syntactic processing. In *Linguistic Structure in Language Processing*. Edited by Greg N. Carlson and Michael K. Tanenhaus. Dordrecht: Kluwer, pp. 157–96.

Bock, J. Kathryn, and Zenzi M. Griffin. 2000. The persistence of structural priming: Transient activation or implicit learning? *Journal of Experimental Psychology: General* 129: 177–92. [CrossRef]

Branigan, Holly P., Martin J. Pickering, and Alexandra A. Cleland. 2000. Syntactic co-ordination in dialogue. *Cognition* 75: B13–B25. [CrossRef] [PubMed]

Bredel, Ursula, and Christiane Maaß. 2016. *Leichte Sprache: Theoretische Grundlagen und Orientierung für Die Praxis*. Berlin: Dudenverlag.

Chang, Franklin. 2002. Symbolically speaking: A connectionist model of sentence production. *Cognitive Science* 26: 609–51. [CrossRef]

Chang, Franklin, and Hartmut Fitz. 2014. Computational models of sentence production: A Dual-Path approach. In *The Oxford Handbook of Language Production*. Edited by Matthew Goldrick, Victor S. Ferreira and Michele Miozzo. Oxford: Oxford University Press.

Chang, Franklin, Gary S. Dell, and Kathryn Bock. 2006. Becoming syntactic. *Psychological Review* 113: 234–72. [CrossRef]

Chang, Franklin, Gary S. Dell, Kathryn Bock, and Zenzi M. Griffin. 2000. Structural priming as implicit learning: A comparison of models of sentence production. *Journal of Psycholinguistic Research* 29: 217–29. [CrossRef] [PubMed]

Chang, Franklin, Marius Janciauskas, and Hartmut Fitz. 2012. Language adaptation and learning: Getting explicit about implicit learning. *Language and Linguistics Compass* 6: 259–78. [CrossRef]

Cleland, Alexandra A., and Martin J. Pickering. 2003. The use of lexical and syntactic information in language production: Evidence from the priming of noun-phrase structure. *Journal of Memory and Language* 49: 214–30. [CrossRef]

Dell, Gary S., and Franklin Chang. 2014. The P-chain: Relating sentence production and its disorders to comprehension and acquisition. *Philosophical Transactions of the Royal Society B: Biological Sciences* 369: 20120394. [CrossRef] [PubMed]

Ferreira, Victor S., and Kathryn Bock. 2006. The functions of structural priming. *Language and Cognitive Processes* 21: 1011–29. [CrossRef] [PubMed]

Friston, Karl. 2018. Does predictive coding have a future? *Nature Neuroscience* 21: 1019–21. [CrossRef] [PubMed]

Goldberg, Adele E., and Devin Casenhiser. 2008. Construction learning and second language acquisition. In *Handbook of Cognitive Linguistics and Second Language Acquisition*. Edited by Peter Robinson and Nick C. Ellis. New York: Routledge, pp. 197–215.

Goldhahn, Dirk, Thomas Eckart, and Uwe Quasthoff. 2012. Building large monolingual dictionaries at the Leipzig Corpora Collection: From 100 to 200 languages. Paper presented at the 8th International Language Resources and Evaluation Conference, Istanbul, Turkey, May 21–27. Available online: http://www.lrec-conf.org/proceedings/lrec2012/pdf/327_Paper.pdf (accessed on 9 April 2024).

Hale, John. 2001. A probabilistic Earley parser as a psycholinguistic model. Paper presented at the Second Meeting of the North American Chapter of the Association for Computational Linguistics, Pittsburgh, PA, USA, June 1–7; Stroudsburg: Association for Computational Linguistics, pp. 1–8.

Hartsuiker, Robert J., and Casper Westenberg. 2000. Word order priming in written and spoken sentence production. *Cognition* 75: B27–B39. [CrossRef]

Hartsuiker, Robert J., and Herman H. J. Kolk. 1998. Syntactic persistence in Dutch. *Language and Speech* 41: 143–84. [CrossRef]

Hartsuiker, Robert J., Herman H. J. Kolk, and Philippine Huiskamp. 1999. Priming word order in sentence production. *The Quarterly Journal of Experimental Psychology: Section A* 52: 129–47. [CrossRef]

Hartsuiker, Robert J., Sarah Bernolet, Sofie Schoonbaert, Sara Speybroeck, and Dieter Vanderelst. 2008. Syntactic priming persists while the lexical boost decays: Evidence from written and spoken dialogue. *Journal of Memory and Language* 58: 214–38. [CrossRef]

Heyselaar, Evelien, and Katrien Segaert. 2022. Structural priming persists for (at least) one month in young adults, but not in healthy older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 48: 1219–34. [CrossRef] [PubMed]

Huettig, Falk. 2015. Four central questions about prediction in language processing. *Brain Research* 1626: 118–35. [CrossRef]

Ionin, Tania, and Silvina Montrul. 2023. *Second Language Acquisition: Introducing Intervention Research*. Cambridge: Cambridge University Press.

Jacobs, Cassandra L., Sun-Joo Cho, and Duane G. Watson. 2019. Self-priming in production: Evidence for a hybrid model of syntactic priming. *Cognitive Science* 43: e12749. [CrossRef] [PubMed]
Jaeger, T. Florian. 2010. Redundancy and reduction: Speakers manage syntactic information density. *Cognitive Psychology* 61: 23–62. [CrossRef] [PubMed]
Jaeger, T. Florian, and Neal E. Snider. 2013. Alignment as a consequence of expectation adaptation: Syntactic priming is affected by the prime's prediction error given both prior and recent experience. *Cognition* 127: 57–83. [CrossRef] [PubMed]
Kaschak, Michael P. 2007. Long-term structural priming affects subsequent patterns of language production. *Memory and Cognition* 35: 925–37. [CrossRef] [PubMed]
Kaschak, Michael P., Timothy J. Kutta, and Christopher Schatschneider. 2011. Long-term cumulative structural priming persists for (at least) one week. *Memory and Cognition* 39: 381–88. [CrossRef] [PubMed]
Kopf, Kristin. 2021. Stellung des adnominalen Genitivs. In *Determination, Syntaktische Funktionen der Nominalphrase und Attributio*. Edited by Marek Konopka, Angelika Wöllstein and Ekkehard Felder. Heidelberg: Heidelberg University Publishing, pp. 103–34.
Kopf, Kristin, and Thilo Weber. 2022. Zum Genitiv im Sprachgebrauch: Sammlungen authentischer Sprachbelege als Beitrag zur modernen Grammatikforschung. *Sprachreport* 3: 1–7.
Kuznetsova, Alexandra, Per B. Brockhoff, and Rune Haubo Bojesen Christensen. 2017. lmerTest package: Tests in linear Mixed Effects Models. *Journal of Statistical Software* 82: 1–26. [CrossRef]
Leipzig Corpora Collection. 2011. German Newspaper Corpus, Crawled in 2011. Leipzig Corpora Collection. Dataset. Leipzig, Germany. Available online: https://corpora.uni-leipzig.de/?corpusId=deu_news_2011 (accessed on 20 July 2017).
Mahowald, Kyle, Ariel James, Richard Futrell, and Edward Gibson. 2016. A meta-analysis of syntactic priming in language production. *Journal of Memory and Language* 91: 5–27. [CrossRef]
McDonough, Kim, and Pavel Trofimovich. 2013. Learning a novel pattern through balanced and skewed input. *Bilingualism: Language and Cognition* 16: 654–62. [CrossRef]
Pickering, Martin J., and Holly P. Branigan. 1998. The representation of verbs: Evidence from syntactic priming in language production. *Journal of Memory and Language* 39: 633–51. [CrossRef]
Pickering, Martin J., and Victor S. Ferreira. 2008. Structural priming: A critical review. *Psychological Bulletin* 134: 427–59. [CrossRef] [PubMed]
Pickering, Martin J., Holly P. Branigan, and Janet F. McLean. 2002. Constituent structure is formulated in one stage. *Journal of Memory and Language* 46: 586–605. [CrossRef]
R Core Team. 2022. *R: A Language and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing. Available online: http://www.R-project.org (accessed on 1 October 2022).
Rao, Rajesh P. N., and Dana H. Ballard. 1999. Predictive coding in the visual cortex: A functional interpretation of some extra-classical receptive-field effects. *Nature Neuroscience* 2: 79–87. [CrossRef] [PubMed]
Reitter, David, Frank Keller, and Johanna D. Moore. 2011. A computational cognitive model of syntactic priming. *Cognitive Science* 35: 587–637. [CrossRef] [PubMed]
Scheepers, Christoph. 2003. Syntactic priming of relative clause attachments: Persistence of structural configuration in sentence production. *Cognition* 89: 179–205. [CrossRef] [PubMed]
Segaert, Katrien, Linda Wheeldon, and Peter Hagoort. 2016. Unifying structural priming effects on syntactic choices and timing of sentence generation. *Journal of Memory and Language* 91: 59–80. [CrossRef]
Smith, George. 2003. On the distribution of the genitive attribute and its prepositional counterpart in Modern Standard German. *University of Pennsylvania Working Papers in Linguistics* 8: 173–84.
Snodgrass, Joan G., and Mary Vanderwart. 1980. A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory* 6: 174–215. [CrossRef]
Van Lieburg , Rianne, Edwige Sijyeniyo, Robert J. Hartsuiker, and Sarah Bernolet. 2023. The production preferences and priming effects of Dutch passives in Arabic/Berber–Dutch and Turkish–Dutch heritage speakers. *Bilingualism: Language and Cognition* 26: 695–708. [CrossRef]