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Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 46(0)

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Publication Date

2024

Peer reviewed

Severe Storm Warnings for Four-Story Homeowners: Towards a Processing Model of Bracketing Paradoxes

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Abstract

Some German adjective-compound-noun constructions (‘severe storm warning’) exhibit a bracketing paradox where an adjective semantically modifies the first noun N_1 instead of the grammatically required last noun N_2 thus violating compositionality. We present two experiments that examined the interpretation of nominal compounds and bracketing paradoxes. Experiment 1 showed that the semantic match of N_1 and the adjective has a significant impact on the acceptability of Adj- N_1N_2 constructions. Experiment 2 probed the participants’ adjective attachment choices as well as the relationship between attachment and acceptability: While N_2 attachments were most common, many constructions received mixed and some consistently bracketing paradox interpretations. High ratings for Adj- N_2 were predictive of N_2 attachment, but high Adj- N_1 ratings led to bracketing paradox interpretations. These results are partially against grammatical expectations and suggest competition between the nouns for modification, likely due to semantic and/or pragmatic factors.

Keywords: bracketing paradox; nominal compounds; pragmatics; semantics; compositionality; German

Background

German compound nouns such as *Schadenfreude* ‘gloating’ and *Elektrizitätsversorgungsunternehmen* ‘electricity supply company’ are a famously common, productive, and nearly unrestricted class of words. Despite their complexity, the interpretation of these nouns is, in most cases, straightforward, because they are composed of lexemes which typically correspond to existing words. For example, *Kirschbaum* ‘cherry tree’ decomposes into *Kirsch(e)* ‘cherry’ and *Baum* ‘tree’. In German nominal compounds, unlike in English, the last noun is the head of the nominal phrase (“Saure Gurkenfabrik–Bezugnahme auf Ersteinheiten von Komposita,” n.d.). It governs the grammatical properties of the whole compound (e.g., grammatical gender, number) and determines its core meaning. Therefore, a cherry tree (*der_{masc} Kirschbaum*) is a type of tree (*der_{masc} Baum*) and not a type of cherry (*die_{fem} Kirsche*).

When nominal compounds are modified by an adjective, the adjective takes on the morphological properties of the head noun. Nominal compounds together with attributive adjectives can be interpreted in one of two ways. They usually have a canonical reading (1) in which the adjectives modifies the last noun of the compound. However, in some well-attested constructions, the adjective can equally (2) or even preferentially modify the first noun (3)/(5). The latter construction is referred to as a *bracketing paradox* (Abramov, 1992; Bergmann, 1980; Winkler, 2015; Wustmann, 1912). Both

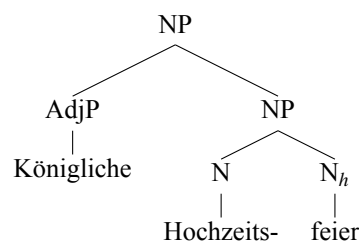


Figure 1: Simplified syntactic representation of the canonical and the bracketing paradox reading of (1) and (2) ‘royal wedding celebration’.

construction types appear to have the same syntactic bracketing (Fig. 1) and stress pattern, unlike English (Newell, 2021). The morphological properties of the adjective match those of the second noun in either construction. However, the semantic bracketing differs between the interpretations (1)/(2), thus seemingly violating compositionality principles (Frege, 1892).

From a grammatical standpoint, the adjective should apply to the second noun or to the compound as a whole (3), but—crucially—not to the first noun (Burkhardt, 1999; Duden Online, n.d.; Fabricius-Hansen, 1993). Despite these constraints, bracketing paradoxes are ubiquitous. They appear in a broad spectrum of print media, from newspaper articles, commercials, to novels. Speakers can spontaneously produce novel bracketing paradoxes and be understood by their interlocutors.

How, then, are bracketing paradoxes licensed and interpreted? If the adjective is able to attach to the nominal compound’s non-head, why are some such phrases odd (4), while others are completely unremarkable (5)? Context, world knowledge, and pragmatic factors are potential contributors to interpretation preferences, along with semantic transparency and morphosyntactic agreement. Language economy and how lexicalized the compound is likely play a role, as well as the semantic compatibility between the adjective and nouns (Bär, 2007; Egg, 2006; Härtl, 2013; Larson, 1998; Maienborn, 2020; Schlücker, 2014; Smolka & Libben, 2017; Spalding et al., 2010).

This multitude of possible factors calls for a broad empirical basis to enable further progress. However, empirical data on this phenomenon is virtually non-existent (Dima et

al., 2017), despite a large body of theoretical and psycholinguistic literature on compounds (Badecker, 2001; Juhasz et al., 2014; Kuperman et al., 2009; Marelli & Luzzatti, 2012; Schäfer, 2018; Taft & Forster, 1976). Here, we present two questionnaire studies which begin to close this gap and lay the foundations for a comprehensive model of bracketing paradoxes.

- (1) Canonical reading:

[Königliche [Hochzeitsfeier]
Royal_{fem} wedding_{fem}.celebration_{fem}]

A grand or royal-themed celebration of a wedding

- (2) Bracketing paradox reading:

[[Königliche Hochzeits]feier]
Royal_{fem} wedding_{fem}.celebration_{fem}]

A wedding celebration involving royalty

- (3) Only canonical reading:

✘ Chemie ✔ Professor

Verrückter Chemieprofessor
Crazy_{masc} chemistry_{fem}.professor_{masc}

Crazy professor of chemistry

- (4) Only bracketing paradox reading:

✔ Haus ✘ Besitzer

? Vierstöckiger Hausbesitzer
Four.story_{masc} house_{neut}.owner_{masc}

Four-story homeowner

- (5) Only bracketing paradox reading:

✔ Unwetter ✘ Warnung

Schwere Unwetterwarnung
Severe_{fem} weather_{neut}.warning_{fem}

Severe weather warning

Experiment 1

Experiment 1 investigated the role of semantic compatibility between the adjective and the individual nouns in the adjective-nominal-compound construction. The degree to which the adjective matches the nouns as well as the compound as a whole is one element of the bracketing paradox potential of the phrase (Dima et al., 2017). Dima et al. present a corpus-based frequency model of German bracketing paradoxes, which predicts that the higher the relative semantic plausibility of the adjective modifying the first noun compared to the second noun, the more likely it is that an adjective and nominal compound phrase form a bracketing paradox. Their corpus study was supplemented by a handful of expert annotators judging the appropriateness of the adjective with both the compound and individual nouns. This first effort would benefit from a broader and more diverse range of participants.

Similarly, Smolka and Libben (2017) investigated the effects of semantic transparency in the lexical processing of German compounds. The authors showed that compound frequency facilitated interpretation and the compound constituents competed in processing with their lexical counterparts. However, their study was not concerned with adjectives.

From a grammatical and strictly compositional standpoint, the compound's acceptability is determined by the agreement between the adjective and the second noun. From this perspective, the first noun has at best a minor contribution to the acceptability of the entire compound. There is evidence from English that the adjective has access to both the modifier and the head noun in a nominal compound modified by an attributive adjective (Berg, 2011). However, there are substantial differences between English and German and the latter has not been investigated empirically in this context.

The goal of this experiment was to establish a baseline for the adjective-noun compatibility, identify phrases with bracketing paradox potential, and investigate how the acceptability of a nominal compound modified by an adjective relates to the acceptability of the nouns together with the adjective.

Methods

Materials Based on the theoretical literature and newspaper articles, we compiled a list of adjective and nominal compound phrases, as in (6). The compounds consisted of exactly two nouns. The constructions included likely bracketing paradoxes, compositional constructions, and unclear cases. 204 items in three conditions were divided into lists using a Latin square design.

- (6) a. Whole compound condition (Adj-N₁N₂)
 Psychologische Beratungsstelle
Psychological_{fem} counseling_{fem}.center_{fem}
- b. First noun condition (Adj-N₁)
 Psychologische Beratung
Psychological_{fem} counseling_{fem}
- c. Second noun condition (Adj-N₂)
 Psychologische Stelle
Psychological_{fem} center_{fem}

Participants 36 participants recruited on Prolific were randomly distributed into one of three lists (mean age 37, 14 women, 1 non-binary). All participants were native speakers of German from Germany or Austria. They reported no issues relating to reading, cognitive or neurological processing. They completed the experiment online from their own PC.

Procedure The participants assigned 1–5 values to the items on the dimensions of naturalness, comprehensibility, and stylistic form on three Likert scales, based on Schmidt (1993). The experiment was programmed using PCIbex (Zehr & Schwarz, 2022). The phrase and three scales were displayed simultaneously. The participants had unlimited time

to respond and could change their minds until they moved to the next phrase.

Predictions Strict grammaticality and compositionality dictate that the ratings for the adjective and second noun condition should be predicative of the adjective and compound's rating. This follows from the syntactic structure of the phrase, where the second noun is the head of the compound (Fig. 1). In compounds where the adjective is compatible with the second noun, the interpretation preferences are likely straightforward and compositional.

When the adjective matches the first noun, the compound is a good candidate for a bracketing paradox. However, it is unclear whether the adjective and compound phrase will receive positive ratings, as bracketing paradoxes can be unassuming, gaudy, or anything in between.

The remaining compounds with similarly distributed ratings between the nouns will have an ambiguous interpretation and, to a lesser degree, a bracketing paradox potential.

Results

Scales The participants gave higher scores on the comprehensibility scale ($mean = 3.7$, $sd = 0.7$), followed by the naturalness ($mean = 3.5$, $sd = 0.7$) and style ($mean = 3.5$, $sd = 0.6$) scales. The ratings across the scales were highly correlated (lowest $r \geq 0.95$, $p < 0.001$). We, therefore, used the mean of these ratings which was scaled to the interval $[0, 1]$ for the analysis. A Bayesian Beta regression modeled the rating based on the judgment scale. The phrases received higher comprehensibility ratings compared to the other scales ($\beta = 0.25$, 95%-CrI $[0.10, 0.39]$), whereas there was no difference between the dimensions of naturalness and stylistic form ($\beta = -0.09$, 95%-CrI $[-0.22, 0.04]$).

Ratings All but three items received good ratings for either Adj-N₁ or Adj-N₂ or for both (Fig. 2A). This is due to our attempt to exclude constructions where the adjective was a poor match for both nouns. Phrases in which the adjective does not fit either of the compound's constituents are unlikely to be produced. This constraint led to a negative correlation between Adj-N₁ and Adj-N₂ ratings ($r = -0.5$).

We fit a Bayesian Beta regression that modeled the averaged and scaled ratings of the Adj-N₁N₂ constructions as a function of the corresponding Adj-N₁ and Adj-N₂ ratings along with their interaction (Bürkner, 2017). Predictors' effects with 95% credible intervals are shown in Fig. 2A–C and Tab. 1. We found two main effects as well as an interaction between the factors.

As expected, high Adj-N₂ ratings were predictive of high Adj-N₁N₂ ratings (Fig. 2B). However, Adj-N₁ ratings, too, had a positive, albeit smaller effect on Adj-N₁N₂ ratings. Crucially, there was an interaction of the Adj-N₁ and Adj-N₂ ratings (Fig. 2C): When Adj-N₂ ratings were low, Adj-N₁ ratings had a substantial positive effect. When Adj-N₂ ratings were high, higher Adj-N₁ ratings slightly *reduced* the Adj-N₁N₂ ratings, suggesting a perceived conflict.

Discussion

The results of the experiment are consistent with the idea that the compatibility between the second constituent noun and an attributive adjective has a vast influence on the acceptability of the entire compound. However, the first noun also plays an important role and contributes to the overall acceptability of the adjective-compound phrase.

When both nouns are good matches for the adjective, acceptability is slightly reduced suggesting a perceived conflict between the possible attachment sites. This result is somewhat corroborated by the findings of Smolka and Libben (2017). Thus, even though both nouns have a positive influence on the compound's acceptability, their effects are not strictly additive. In the absence of a suitable head noun candidate, the first noun becomes an attractive modification target for the adjective.

The comprehensibility, naturalness and stylistic form scores were highly correlated, indicating that they record similar concepts. This is especially true for the latter two scales. It could be that they are either similar in nature or were interpreted as such. The comprehensibility scores were consistently higher than the other scales. This could indicate that participants recognized a conflict or a mismatch between the (compound) noun and the adjective, but still tried to find a valid interpretation for the phrase.

Having established a baseline acceptability for the adjective-compound phrases, we can move to determining more directly which constituent noun is the modifiee of the adjective attribute.

Experiment 2

The second study directly probed which noun in a compound is modified by the adjective. The adjective's attachment site is not necessarily determined by the ratings obtained in Experiment 1. Some bracketing paradoxes are so inconspicuous, that they may receive good ratings. On the other hand, despite our efforts, the items in the previous experiment contained a handful of constructions where both nouns were a poor match for the adjective. By asking the participants to specify which noun is modified by the adjective we can determine whether an adjective-compound pair has a canonical interpretation or is a bracketing paradox.

From a grammatical point of view, the adjective should be an attribute of the second noun in the compound. However, if there are adjective-compound pairs where the adjective modifies the first noun, then these phrases are bracketing paradox candidates. Similarly, when a phrase is ambiguous, then the adjective can equally plausibly modify either of the nouns. It could also be that for some of the phrases, it is unclear whether an interpretation is possible at all. In the latter two of these cases, the reader could opt out of parsing the construction altogether.

Finally, we sought to verify whether the compatibility ratings from Experiment 1 align with the selected attachment site, as indicated by participants in this study.

	Estimate	Est.Error	1-95% CrI	u-95% CrI	Rhat	Bulk ESS	Tail ESS
Intercept	-4.02	0.76	-5.62	-2.60	1.00	3357	3907
Adj-N ₁	3.32	0.89	1.67	5.17	1.00	3383	3757
Adj-N ₂	6.34	0.89	4.69	8.19	1.00	3291	3916
Adj-N ₁ × Adj-N ₂	-4.01	1.07	-6.20	-1.99	1.00	3378	3748

Table 1: Summary of the model effects in Experiment 1 for ratings.

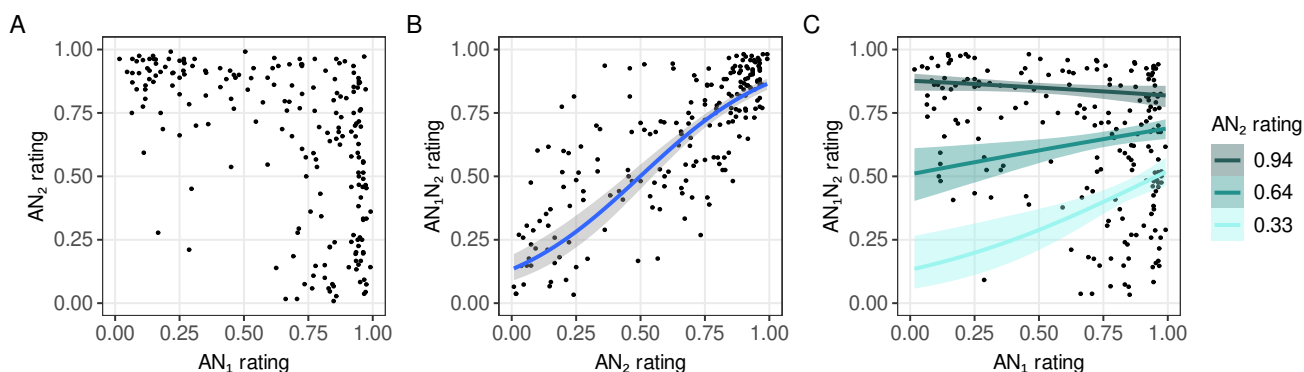


Figure 2: Experiment 1 results. **A:** Relationship between Adj-N₂ and Adj-N₁. **B:** Relationship between Adj-N₁N₂ and Adj-N₂. **C:** Relationship between Adj-N₁N₂ and Adj-N₁. Lines correspond to Adj-N₂ groups.

In sum, the goal of this experiment was to determine which noun of the compound is modified by the adjective and whether the ratings in Experiment 1 are correlated with the participants’ intuitions about the adjective’s attachment site.

Methods

Materials The adjective and nominal compound pairs from Experiment 1 were supplemented by further examples gathered from theoretical literature and newspaper articles. Overall, 235 Adj-N₁N₂-phrases were presented to all participants in only one condition (6a).

Participants 20 participants were recruited on Prolific (mean age 36, 6 women, 1 non-binary). They reported no issues relating to reading, cognitive or neurological processing. They were German native speakers from Germany or Austria and could complete the experiment online from their PC.

Procedure The participants indicated for the Adj-N₁N₂-phrases whether the adjective modifies N₁, or N₂, or whether they were unsure. Each adjective and compound phrase was presented individually and the participants made a choice while reading the phrase. They had to make a choice before moving to the next item. The study was programmed in PCIBex.

Predictions The second noun should be the most selected option as the modifiee of the adjective attribute, as dictated by grammar. There should be a smaller group of compounds which favor the first noun. This is not only expected based on the results from Experiment 1, but also because the materials contain examples of bracketing paradoxes discussed in

the theoretical literature.

High ratings for Adj-N₂ items should correspond to a higher proportion of N₂ responses. Likewise, high ratings for Adj-N₁ items should correspond to a lower proportion of N₂ responses. Ambiguous or unclear cases may be those where the Adj-N₁ and Adj-N₂ ratings are similar.

Results

Adjective attachment site Participants overwhelmingly selected one of the nouns, with only < 3% “unsure” answers (Fig. 3A). Therefore, we excluded “unsure” answers from the analysis. For 99 compounds (42% of the items), 90% of participants chose the second noun as the attachment site. 90% of participants chose the first noun for only 14 compounds (6% of the items). 70 compounds (30% of the items) exhibited a highly variable attachment preferences, with 6 to 14 votes for either N₁ or N₂.

Comparison to Experiment 1 An overview of the ratings relative to the noun choices is presented in Fig. 3B–C. A Bayesian logistic regression modeled the choice of attachment site (N₂ or not N₂) as a function of the corresponding Adj-N₁ and Adj-N₂ ratings from Experiment 1, along with their interaction. Predictors’ effects with 95% credible intervals are shown in Fig. 3C–D and Tab. 2. Only the items present in both experiments were used for this analysis. The analysis revealed two main effects as well as an interaction.

High Adj-N₂ ratings were predictive of more N₂ attachment. On the other hand, high Adj-N₁ ratings reduced the rate of N₂ attachment. When Adj-N₂ ratings were low, high Adj-N₁ had a stronger effect on N₂ attachment. When Adj-

	Estimate	Est.Error	l-95% CrI	u-95% CrI	Rhat	Bulk ESS	Tail ESS
Intercept	-0.72	0.50	-1.65	0.30	1.00	1962	2002
Adj-N ₁	-1.33	0.59	-2.52	-0.21	1.00	1930	1972
Adj-N ₂	8.01	0.80	6.47	9.58	1.00	1645	2064
Adj-N ₁ × Adj-N ₂	-5.65	0.96	-7.54	-3.81	1.00	1658	1823

Table 2: Summary of the model effects in Experiment 2: attachment site relative to rating in Experiment 1.

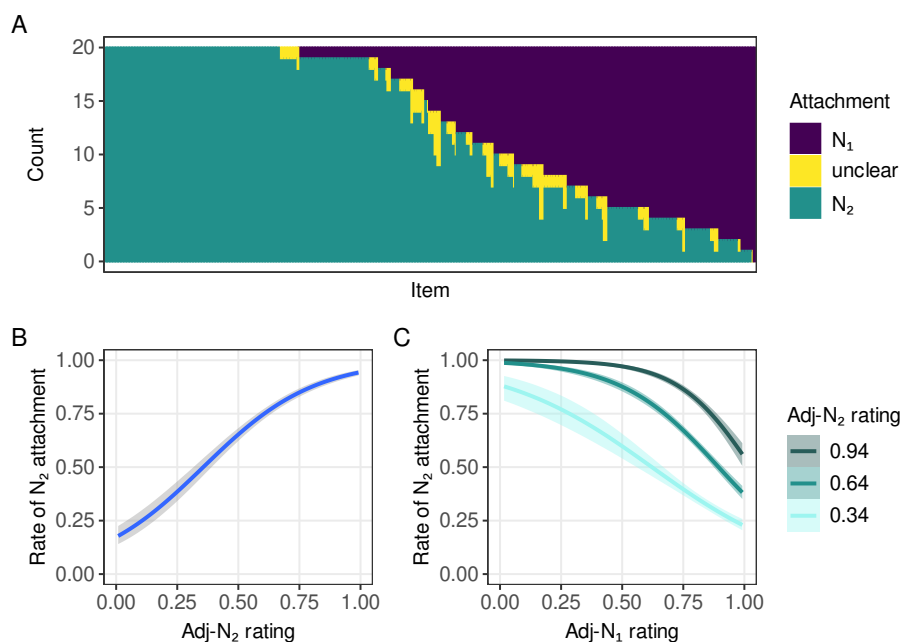


Figure 3: Experiment 2 results. **A:** Attachment choices in items, ordered by number of N₁/N₂/unclear answers. **B:** Relationship between Adj-N₁ rating and N₂ adjective attachment. **C:** Relationship between attachment preference and Adj-N₁ rating. Lines correspond to Adj-N₂ groups.

N₂ ratings were high, Adj-N₁ had a lesser influence on N₂ attachment.

Discussion

Overall, the participants did not opt out of interpreting the adjective and compound phrases. This is in spite of some of the items having been poorly rated in the first study. Even in those cases, that the choice of the adjective's modifée was still conceivable and participants tried to complete the experimental task whenever possible. For a substantial part of the phrases, the participants agreed on the choice of noun modifée. The most frequent referent was the second noun, but for a large group of phrases, the first noun was viable as well. There was a small group of phrases that received unanimous bracketing paradox interpretations. Among the phrases were (5) and (6a), as well as *saurer Kirschbaum* 'sour cherry tree': the only phrase to receive only N₁ responses.

This outcome is consistent with the expectation that, following grammatical rules, the adjective is preferentially attached to the second noun. Moreover, the presence of bracketing paradoxes is in line with our predictions as well.

There was a substantial group of constructions where the opinions diverged. Some participants chose the canonical interpretation, whereas others the bracketing paradox one. This points to an ambiguity, which might result from a competition between the nouns for modification. Numerous phrases described as bracketing paradoxes in theoretical literature were in this category as well and did not have the expected categorical preference for the first noun. For example *braune Hirschstraße* 'brown deer street' (Abramov, 1992) and *wichtiger Ansatzpunkt* 'important starting point' (Bergmann, 1980) received a comparable amount of N₁ and N₂ responses. Unlike for the phrases with a straightforward second noun attachment, the bracketing paradoxes blended into a gradual ambiguity spectrum.

Therefore, there seems to be a more fundamental difference between what is an acceptable and unacceptable bracketing paradox as well as what constitutes an ambiguous phrase. This could mean that bracketing paradoxes have a context or a world-knowledge dependent interpretation, which is favored or suppressed during interpretation. In our experiment, there were neither disambiguating circumstances nor a narrow

context. Therefore, the participants had to draw conclusions based on their individual preferences.

Lastly, the comparison with the findings in Experiment 1 was in line with our predictions. The effect of Adj-N₂ compatibility was the strongest influence on the adjective attachment site choice. The phrases in which the adjective was compatible with the second noun were more likely to be interpreted canonically. The ratings for the entire adjective-compound phrase had a similar but much weaker influence. This result is consistent with the grammatical expectation that the adjective attaches primarily to the final constituent in the compound.

When the adjective and the first noun were a good fit, the participant were more likely to disagree on the choice of attachment site. This effect was particularly pronounced when the adjective and the second noun were a poor match. An interpretational ambiguity or a reading of the phrase involving a bracketing paradox could account for this outcome, similar the processing of a garden-path sentence (MacDonald et al., 1994).

Conclusions and outlook

Contrary to the grammatical and strictly compositional constraints on their relationship, the first noun plays an important role in the acceptability of a nominal compound modified by an adjective. The first noun contributes to the overall interpretation, despite the second noun's dominance over the adjective and compound. Its influence is evidenced by both the acceptability judgments and the referent choices. This outcome aligns with the role of semantic and pragmatic factors in such constructions. These aspects may lead to interpreters favoring an attachment site that is otherwise grammatically unavailable.

When both nouns are well-suited for the adjective, the phrase's acceptability is slightly reduced suggesting a perceived conflict or competition between the possible attachment sites. This is corroborated by the fact the modiffee preference was unclear for a large group of the phrases. Thus, even though both nouns have a positive effect on the compound's acceptability, their effects are not additive.

In the absence of a suitable head noun candidate, the first noun becomes an attractive modification target for the adjective. However, for a large group of phrases, including the bracketing paradox examples in theoretical literature, the interpretation is evidently not straightforward. Contextual or pragmatic factors are likely involved in guiding the choice of adjective attachment.

This work suggests that the interpretation of bracketing paradoxes is not a clear-cut choice between the nouns, and there is much uncertainty and disagreement on the intended interpretation between both laypeople and experts in the field.

There are several open questions that remain unanswered. What distinguishes the natural (6a) from the unnatural (4) sounding bracketing paradoxes? Is this difference related to the compound's frequency, the semantic transparency, or the extent to which the compound is lexicalized as a concept?

Some nominal compounds such as *Regenschirm* (umbrella) or *Tierarzt* (veterinarian) are frequently used and may not be deconstructed into lexemes. Were this the case, the lexical entry of the entire compound would already contain the properties of the individual nouns. Therefore, the adjective would be free to attach to whichever element is appropriate. Other compounds such as *Wintersonne* 'winter sun' or *Bienenparadies* 'bee paradise' are rare or constructed ad hoc. The meaning of their constituents is crucial for the overall interpretation. This dichotomy could play a role in the online processing and how well the resulting interpretation fits within a larger context.

How do speaker and listener agree on an interpretation of compound nouns modified by an adjective in ambiguous cases? Bracketing paradoxes are used in some contexts where brevity is preferred or in which they are used for comedic effect. Discourse information may influence the acceptability and the interpretation of these constructions. For example, (4) could be described as (7a) or (7b). The former description is concise but potentially ambiguous, whereas the latter is clear and precise, but much longer. In a newspaper article or in a context where repeating (7b) would lead to unnecessary repetition of long phrases, the speaker might opt for a shorter formulation despite associated processing difficulties. This is even more the case in works of fiction or contexts where the ambiguity may be part of the message.

- (7) a. ? der vierstöckige Hausbesitzer
the four.story house.owner
the four-story homeowner
b. der Besitzer eines vierstöckigen Hauses
the owner of.a four-story house
the owner of a four-story house

Another factor which can influence the interpretational preferences is morphosyntactic agreement (gender and number). In German adjective and compound noun phrases, the adjective adjusts its morphological information according to the compound-final component. When morphological elements differ between the nouns of a compound, the adjective could bias the reader towards the canonical interpretation. When both nouns have the same gender or number, the bracketing paradox interpretation could more easily be available.

In sum, this research challenges grammatical constraints by revealing the significant role of the first noun in the interpretation of nominal compounds modified by adjectives, even when the second noun dominates in both acceptability and choice of attachment site. These results align with the impact of semantic and pragmatic factors on such constructions, suggesting an occasional preference for an attachment site that is grammatically unavailable. The studies raise several interesting questions for future work, exploring factors such as the appropriateness of head noun candidates, the impact of contextual or pragmatic influences, and the distinctions between natural and unnatural sounding bracketing paradoxes. More broadly the results add to existing evidence suggesting that compositional processing can be suspended when that serves communicative goals.

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